Chapter 5:
Ecological Condition

Indicators selected and included in this chapter were assigned to one of two categories:

- **Category 1** - The indicator has been peer reviewed and is supported by national level data coverage for more than one time period. The supporting data are comparable across the nation and are characterized by sound collection methodologies, data management systems, and quality assurance procedures.
- **Category 2** - The indicator has been peer reviewed, but the supporting data are available only for part of the nation (e.g., multi-state regions or ecoregions), or the indicator has not been measured for more than one time period, or not all the parameters of the indicator have been measured (e.g., data has been collected for birds, but not for plants or insects). The supporting data are comparable across the areas covered, and are characterized by sound collection methodologies, data management systems, and quality assurance procedures.

5.0 Introduction

As described in Chapter 4, Human Health, EPA is moving in the direction of measuring outcomes that reflect the actual impacts that result from environmental pollution. This chapter applies that approach to ecosystems. Previous chapters examined impacts on air, water, and land—all elements of the environment that EPA seeks to protect. This chapter links the state of the nation's air, water, land, and living organisms into a broad framework termed "ecological condition"—the sum total of the physical, chemical, and biological characteristics of the environment, and of the resulting processes and interactions among them.[1] Understanding ecological condition is crucial, because humans depend on ecosystems for food, fiber, flood control, and countless other critical "services" they provide to society (Daily, 1997). Many Americans also attribute deep significance and important intangible benefits to ecosystems and their diverse flora and fauna.

Ecological condition reflects the result of a complex array of factors, including natural disturbances, invasions of new species, resource management, planning and zoning, and pollution. EPA has statutory authority to regulate only a few of these factors, but it exerts policy leadership across a broad spectrum of public and private activities, including review of significant federal projects under the National Environmental Policy Act (NEPA). These efforts reflect the EPA's important role as one of many federal, tribal, state, and local government and private partners in protecting the nation's environment.

This chapter asks questions about our current understanding of the ecological condition of:

- Forests
- Farmlands
- Grasslands and shrublands
- Urban and suburban areas
- Fresh waters
- Coasts and oceans
- The entire nation[2]

Exhibit 5-1 is a depiction of the events that link environmental changes to ecological outcomes. "Stressors," indicated by arrows, represent factors such as insect outbreaks or pollutants affecting the system. These act directly on one or more of the "essential ecological attributes" shown in the circles in the center of the diagram. (These attributes are described in more detail below.) Each of these attributes can, in turn, act on and be acted on by others. The web of arrows among the indicators illustrates some of the possible interactions. Effects on ecological attributes can be direct or indirect. This diagram illustrates the fact that ecological processes have important feedbacks on the chemical and physical structure of the environment in which these changes occur. The overall changes in the attributes result in altered structure and function of the ecosystem, which in turn lead to outcomes (good or bad) about which society is concerned.

Exhibit 5-1 shows that monitoring only stressors or monitoring single ecosystem attributes–such as living things–in isolation cannot convey a full and accurate picture of ecological condition. Assessments of ecological condition must incorporate measures of different characteristics, potentially at different times and in different places within a system. EPA can build on decades of monitoring stressors to develop and appropriately monitor multidimensional and better-linked ecological condition indicators.

This chapter presents initial work toward identifying indicators that can help to answer the question "What is the ecological condition of the U.S.?" and it can help elucidate the sequence of events shown in Exhibit 5-1. The chapter is organized into nine sections that describe:

- The framework used in this report to identify indicators to assess ecological condition and outcomes (Section 5.1).
- The ecological condition of forests (Section 5.2), farmlands (Section 5.3), grasslands and shrublands (Section 5.4), urban and suburban areas (Section 5.5), fresh waters (Section 5.6), coasts and oceans (Section 5.7), and the entire nation (Section 5.8).
- The key challenges and data gaps for developing adequate indicators of ecological condition (Section 5.9).

Because ecological condition depends critically on the physical and chemical characteristics of land, air, and water, this chapter draws on indicators from Chapters 1 through 3 of this report, as shown in Exhibit 5-2. Those chapters should be consulted for the data sources for those indicators. Many of the indicators were drawn from The H. John Heinz III Center for Science, Economics, and the Environment (The Heinz Center) report, T*he State of the Nation's Ecosystems: Measuring Lands, Waters, and Living Resources of the United States*, 2002, which also presents more detail on data sources, as does Appendix B of this report.

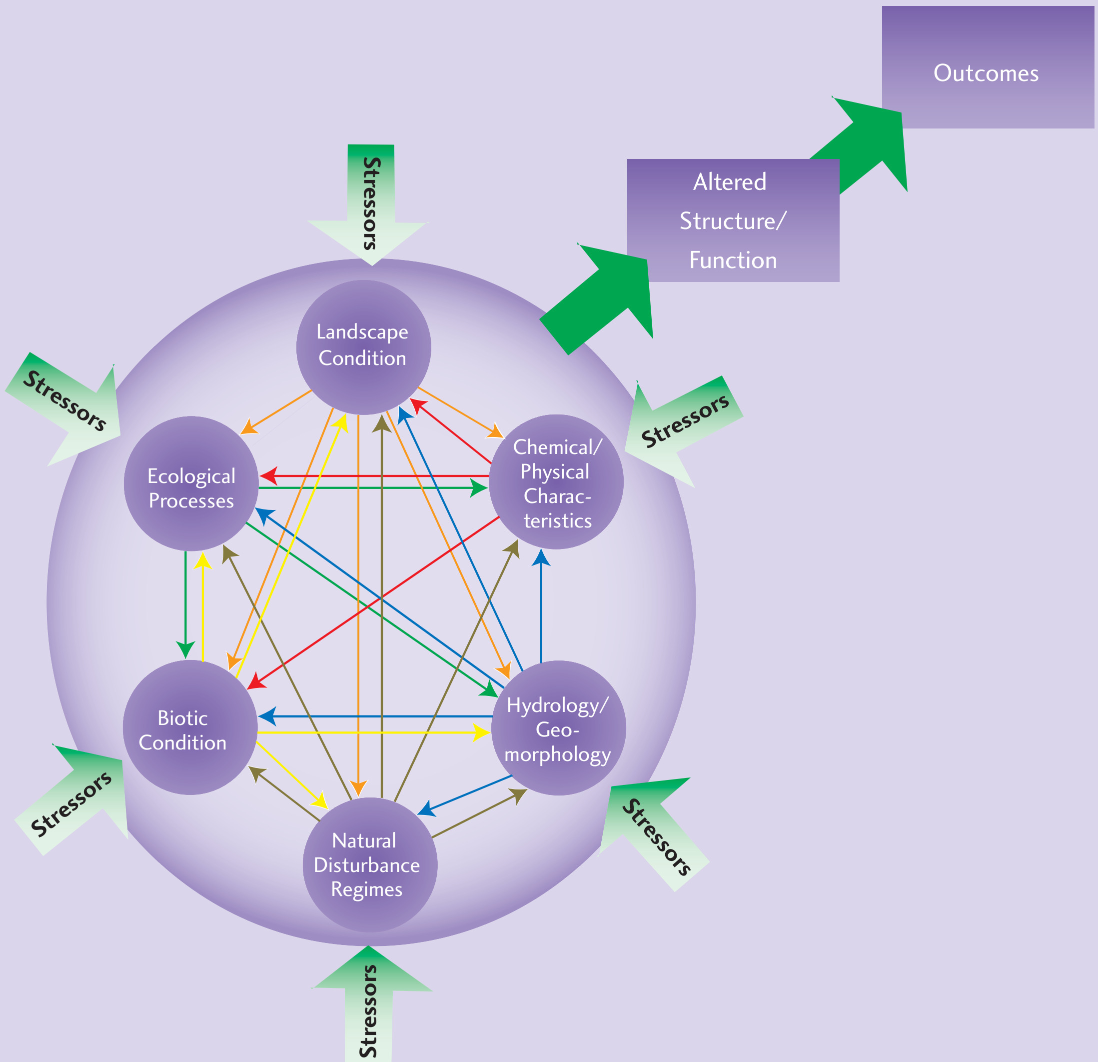
The key data sources reflect the fact that monitoring ecological condition is a multi-organizational task. Organizations in addition to EPA that are responsible for collecting the data to support indicators in this chapter include:

- The U.S. Department of Commerce (National Oceanic and Atmospheric Administration)
- National Aeronautics and Space Administration
- The U.S. Department of Agriculture (Forest Service, Agricultural Research Service, National Agricultural Statistics Service, and Natural Resource Conservation Service)
- The U.S. Department of Interior (U.S. Geological Survey and U.S. Fish and Wildlife Service)
- NatureServe, a private foundation

[1] The term *ecosystem* is used in its broadest sense as any interacting system of physical, chemical, and biological components and the associated flows of energy, material, and information (Odum, 1971).

[2] This seventh category refers to the overall condition of the complex, interconnected mosaic of different ecosystem types across the entire nation.

Exhibit 5-1: Ecological condition paradigm



Together, the six ecological attributes constitute "ecological condition."

Stressors (shown as) affect ecological attributes directly and also indirectly through feedback (interaction)among the attributes ( )

Programs such as the U.S. Department of Agriculture Forest Inventory and Analysis (FIA) program and the Natural Resources Inventory (NRI) have a long history, because they measure aspects of the environment that are critical to multi-billion dollar industries (e.g., timber, crops, etc.). Programs with a strictly "ecological" focus (e.g., the USDA Forest Service Forest Health Monitoring [FHM] Program, the U.S. Geological Survey National Water Quality Assessment Program [NAWQA], the multi-agency Multi-Resolution Land Characterization Consortium [MRLC], and EPA's Environmental Monitoring and Assessment Program [EMAP]) are newer on the scene, and most have produced only Category 2 indicators as this report goes to press.

Like Chapter 4, Human Health, this chapter is not intended to be exhaustive. Rather, it provides a snapshot, at the national level, of current U.S. ecological condition indicators and status based on key data sources with sufficiently robust design, quality assurance, and maturity.

Exhibit 5-2: Ecological Condition - Questions and Indicators

Forests

Question	Indicator Name	Category	Section
What is the ecological condition of forests?	*Extent of forest area, ownership, and management*	*1*	*3.1.4*
	Nitrate in farmland, forested, and urban streams and ground water	*2*	*2.2.4.b*
	Deposition: wet sulfate and wet nitrogen	*2*	*1.2.2*
	Changing stream flows	*1*	*2.2.4.a*
	Extent of area by forest type	1	5.2
	Forest age class	2	5.2
	Forest pattern and fragmentation	2	5.2
	At-risk native forest species	2	5.2
	Populations of representative forest species	2	5.2
	Forest disturbance: fire, insects, and disease	1	5.2
	Tree condition	2	5.2
	Ozone injury to trees	2	5.2
	Carbon storage	2	5.2
	Soil compaction	2	5.2
	Soil erosion	2	5.2
	Processes beyond the range of historic variation	2	5.2

Farmlands

Question	Indicator Name	Category	Section
What is the ecological condition of farmlands?	*Extent of agricultural land uses*	*1*	*3.1.2*
	The farmland landscape	*1*	*3.1.2*
	Nitrate in farmland, forested, and urban streams and ground water	*2*	*2.2.4.b*
	Phosphorus in farmland, forested and urban streams	*2*	*2.2.4.b*
	Pesticides in farmland streams and ground water	*2*	*2.2.4.c*
	Potential pesticide runoff from farm fields	*2*	*3.2.4*
	Sediment runoff potential from croplands and pasturelands	*2*	*3.1.6*
	Pesticide leaching potential	2	5.3
	Soil quality index	2	5.3
	Soil erosion	2	5.3

Grasslands and Shrublands

Question	Indicator Name	Category	Section
What is the ecological condition of grasslands and shrublands?	*Extent of grasslands and shrublands*	*1*	*3.1.3*
	Number/duration of dry stream flow periods in grasslands and shrublands	*2*	*2.2.4.a*
	At-risk native grassland and shrubland species	2	5.4
	Population trends of invasive and native non-invasive bird species	1	5.4

Note: Italicized indicators are presented in other chapters.

Urban and Suburban Lands

Question	Indicator Name	Category	Section
What is the ecological condition of urban and suburban areas?	*Extent of urban and suburban lands*	*1*	*3.1.1*
	Ambient concentrations of ozone: 8-hour and 1-hour	*2*	*1.1.1.b*
	Nitrate in farmland, forested and urban streams, and ground water	*2*	*2.2.4.b*
	Phosphorus in farmland, forested, and urban streams	*2*	*2.2.4.b*
	Chemical contamination in urban streams and ground water	*2*	*2.2.4.c*
	Patches of forest, grassland, shrubland, and wetland in urban/suburban areas	2	5.5

Fresh Waters

Question	Indicator Name	Category	Section
What is the ecological condition of fresh waters?	*Wetland extent and change*	*1*	*2.2.2*
	Altered fresh water ecosystems	*2*	*2.2.1*
	Contaminants in fresh water fish	*2*	*2.5.1*
	Phosphorus in large rivers	*2*	*2.2.4.b*
	Lake Trophic State Index	*2*	*2.2.1*
	Chemical contamination in streams and ground water	*2*	*2.2.4.c*
	Acid sensitivity in lakes and streams	*2*	*2.2.4.c*
	Changing stream flows	*1*	*2.2.4.a*
	Sedimentation index	*2*	*2.2.4.a*
	Extent of ponds, lakes, and reservoirs	1	5.6
	At-risk native fresh water species	2	5.6
	Non-native fresh water species	2	5.6
	Animal deaths and deformities	2	5.6
	At-risk fresh water plant communities	2	5.6
	Fish Index of Biotic Integrity in streams	2	5.6
	Macroinvertebrate Biotic Integrity Index for streams	2	5.6

Coasts and Oceans

Question	Indicator Name	Category	Section
What is the ecological condition of coasts and oceans?	*Chlorophyll concentrations*	*2*	*2.2.3*
	Water clarity in coastal waters	*2*	*2.2.3*
	Total nitrogen in coastal waters	*2*	*2.2.4.b*
	Total phosphorus in coastal waters	*2*	*2.2.4.b*
	Dissolved oxygen in coastal waters	*2*	*2.2.3*
	Total organic carbon in sediments	*2*	*2.2.3*
	Sediment contamination of coastal waters	*2*	*2.2.4.c*
	Sediment toxicity in estuaries	*2*	*2.2.4.c*
	Extent of estuaries and coastline	1	5.7
	Coastal living habitats	2	5.7
	Shoreline types	2	5.7
	Benthic Community Index	2	5.7
	Fish diversity	2	5.7
	Submerged aquatic vegetation	2	5.7
	Fish abnormalities	2	5.7
	Unusual marine mortalities	2	5.7

Note: Italicized indicators are presented in other chapters.

The Entire Nation

Question	Indicator Name	Category	Section
What is the ecological condition of the entire nation?	Ecosystem extent	2	5.8
	At-risk native species	2	5.8
	Bird Community Index	2	5.8
	Terrestrial Plant Growth Index	1	5.8
	Movement of nitrogen	1	5.8
	Chemical contamination	2	5.8

Note: Italicized indicators are presented in other chapters.

5.1 Links Between Stressors and Ecological Outcome: A Framework for Measuring Ecological Condition

The primary reasons to monitor ecological condition are similar to those for monitoring air, water, and land;

- To establish baselines against which to assess the current and future condition.
- To provide a warning that action may be required.
- To track the outcomes of policies and programs, and adapt them as necessary.

Measuring ecological condition is not as straightforward as monitoring water or air to determine whether temperatures or concentrations of pollutants exceed a legal standard, however. Ecosystems are dynamic assemblages of organisms that have more or less continuously adapted to a variety of natural stresses over shorter (e.g., fire, windstorms) and longer (climate variations) periods of time, taking on new and different characteristics. This makes determination of the condition of a "natural" system difficult (Ehrenfeld, 1992). In addition, people have altered natural ecosystems to increase their productivity of food, timber, fish, and game, and to provide the infrastructure needed to support a modern society. How should the ecological condition of these altered ecosystems be measured, and against what reference points? Several recent reports by experts in the field have provided advice to guide current and future efforts.

The National Research Council (NRC) report, *Ecological Indicators for the Nation* (NRC, 2000), provides an introduction to recent national efforts to measure ecological condition and a thoughtful discussion of the rationale for choosing indicators. EPA's Science Advisory Board (SAB) also proposed a *Framework for Assessing and Reporting on Ecological Condition* (EPA, SAB, 2002). The framework identifies six "essential ecological attributes" (EEAs) of ecosystems:

- Landscape condition
- Biotic condition
- Chemical and physical characteristics
- Ecological processes
- Hydrology and geomorphology
- Natural disturbance regimes

The EEAs, along with reporting categories and examples of associated indicators, are displayed in Exhibit 5-3. Neither report identifies specific methodologies, network designs, or actual datasets corresponding to the examples.

The H. John Heinz III Center for Science, Economics, and the Environment (The Heinz Center) led a nationwide effort by government, academia, and the private sector to develop a report entitled T*he State of the Nation's Ecosystems: Measuring Lands, Waters, and Living Resources of the United States* (The Heinz Center, 2002). According to the introduction, the report "provides a prescription for 'taking the pulse' of the lands and waters. It identifies what should be measured, counted, and reported, so that decision-makers and the public can understand the changes that are occurring in the American landscape." The Heinz Center report identified 103 specific indicators, of which 33 were judged by the authors to have adequate data for national reporting.

The Heinz Center report provides an important core of indicators for this chapter. The Heinz Center report uses a somewhat different categorization of indicators than the Category 1 and 2 designations, and indicators identified by The Heinz Center that have inadequate data or need further development have not been included here. The Heinz Center indicators in this chapter are organized around the SAB framework, but given the similarities among the NRC, SAB, and Heinz Center approaches, this choice does not affect the final result. This chapter also includes, in addition to The Heinz Center national indicators, some Category 2 indicators from regional monitoring studies that

Exhibit 5-3: Essential ecological attributes and reporting categories

Landscape Condition
- Extent of Ecological System/Habitat Types
- Landscape Composition
- Landscape Pattern and Structure

Biotic Condition
- Ecosystems and Communities
  - Community Extent
  - Community Composition
  - Trophic Structure
  - Community Dynamics
  - Physical Structure
- Species and Populations
  - Population Size
  - Genetic Diversity
  - Population Structure
  - Population Dynamics
  - Habitat Suitability
- Organism Condition
  - Physiological Status
  - Symptoms of Disease or Trauma

Chemical and Physical Characteristics (Water, Air, Soil, and Sediment)
- Nutrient Concentrations
  - Nitrogen
  - Phosphorous
  - Other Nutrients
- Trace Inorganic and Organic Chemicals
  - Metals
  - Other Trace Elements
  - Organic Compounds
- Other Chemical Parameters
  - pH
  - Dissolved Oxygen
  - Salinity
  - Organic Matter
  - Other
- Physical Parameters

Ecological Processes
- Energy Flow
  - Primary Production
  - Net Ecosystem Production
  - Growth Efficiency
- Material Flow
  - Organic Carbon Cycling
  - N and P Cycling
  - Other Nutrient Cycling

Hydrology/Geomorphology
- Surface and Ground Water Flows
  - Pattern of Source Flows
  - Hydrodynamics
  - Pattern of Ground Water Flows
  - Salinity Patterns
  - Water Storage
- Dynamic Structural Characteristics
  - Channel/Shoreline Morphology, Complexity
  - Extent/Distribution of Connected Floodplain
  - Aquatic Physical Habitat Complexity
- Sediment and Material Transport
  - Sediment Supply/Movement
  - Particle Size Distribution Patterns
  - Other Material Flux

Natural Disturbance Regimes
- Frequency
- Intensity
- Extent
- Duration

Source: EPA, Science Advisory Board. *A Framework for Assessing and Reporting on Ecological Condition.* June 2002.

show promise for implementation on a national scale. Regardless of whether the indicators are Category 1 or 2, all indicators were drawn directly from scientifically defensible studies published in peer-reviewed reports and journals.

One of the most critical data quality objectives of monitoring for EPA is representativeness, the degree to which monitoring data accurately and precisely represent the variations of a characteristic over an entire population (e.g., all streams or forests)[3]. *Sampling design*[4] approaches the problem of representativeness and the effects of sampling and measurement error on environmental management policies and decisions. Sampling designs fall into two main categories, *probability designs and judgmental designs*. Probability designs apply sampling theory, so that any sampling unit (e.g., a stream of a stand of trees in a forest) has a known probability of selection. This important attribute allows the characteristics of the entire population of streams or forest stands to be estimated with known uncertainty, ensures that the results are reproducible within that uncertainty, and enables one to calculate the probability of decision-error based on the uncertainty in the data. Probability designs do not provide information on the precise conditions at any location where measurements are not made, or of the populations during times when measurements are not made,[5] or of populations not included in the sampling design.

Judgmental designs rely on expert knowledge or judgment to select sampling units. They can be easier and less expensive to implement than probability sampling. Monitoring sites selected at random can be difficult or even impossible to access, and some monitoring programs require sites that are easy to access repeatedly, or remote sites from which to search for faint signals such as climate change or long-range transport of pollutants. The accuracy of the results of judgment designs depends on the quality of the professional judgment, but in the best of cases quantitative estimates of uncertainty cannot be made. In this report, Category 1 indicators were required to be based on indicators collected using probability designs or "wall-to-wall" coverage by remote sensing, unless a strong case could be made that the data were representative of the population being sampled.

This chapter follows The Heinz Center (2002) in reporting on six major ecosystem types.[6] With a few exceptions, environmental and natural resource monitoring programs currently are structured to track the condition of individual natural resources (e.g., trees, crops, soil, water, or air) represented by the first six ecosystem types. Though some of this

[3]Like the U.S. Census, which strives to collect data on every person in the U.S., an ecological census could attempt to collect data on every plant, animal, stream, etc. This is generally impossible or cost-prohibitive, except for data collected on land cover or other features of the environment that can be measured by satellite.

[4]Olsen, et al., 1999, and Yoccoz, et al., 2001, provide useful discussions of sampling oriented toward ecological monitoring.

[5]For example, if estuaries are sampled only in the fall, the sample reveals nothing about estuaries in the spring or winter.

monitoring takes place on a national level, it still focuses on discrete resources or ecosystem types. For this reason, most available indicators can help answer questions about the condition of individual ecosystem types, but cannot track the overall ecological condition of an area comprising different interconnected and interacting ecosystem types. Therefore, this chapter includes a seventh category representing indicators potentially suitable for the entire nation.

A few indicators are available to help provide a more holistic assessment of ecological condition at the national level. For example, large or migratory organisms (e.g., bears or neotropical birds, respectively) depend on many ecosystem types over large areas for their continued survival. As another example, all of the terrestrial ecosystems types may contribute nitrogen, carbon, or sediment to streams and rivers in watersheds. Even the arrangement of ecosystems in the landscape and the composition of patterns of land cover and land use have been identified as critical components in the way ecosystems function (Forman and Godron, 1986; Naiman and Turner, 2000; Winter, 2001; EPA, SAB, 2002). Section 5.8 corresponds approximately to the core national indicators in The Heinz Center report.

Ideally, the indicators in this chapter would be presented in a way that spoke to the success of our efforts to protect and restore the ecological condition of the types of ecosystems considered in this chapter. Trends in biotic condition and ecological functions and in the physical, chemical, hydrological, landscape, and disturbance regimes of each ecosystem would provide keys to stories involving acid rain, or landscape fragmentation, or changing climate. The resulting "stories" would establish baselines, provide warnings, and track the effectiveness of management actions by EPA and its partners, as envisioned by the NRC (2000). Because so few reliable data exist on trends for any indicators at the national level, however, such a presentation is not yet possible. Instead, the chapter presents a disturbingly fragmentary picture of what little is known reliably and nationally based on Category 1 indicators. It also anticipates what could reasonably be known if monitoring of Category 2 indicators were to be expanded.

Sections 5.2 through 5.8 below describe the ecological condition of the seven ecosystem types. Each section begins with an introduction that summarizes data on the indicators that appear in the previous chapters of this report on air, water, and land. Indicators presented for the first time then are described in detail. Each section ends with a summary of what the available indicators, taken together, reveal about the ecological condition of that ecosystem type.

5.2 What is the Ecological Condition of Forests?

Forests, as defined by the U.S. Department of Agriculture (USDA) Forest Service (FS), are any lands that are at least 10 percent covered by trees of any size and at least 1 acre in extent (Smith, et al., 2001). Some forested ecosystems are rich sources of biodiversity and recreational opportunities, while others are managed intensively for timber production. All are important for carbon storage, hydrologic buffering, and fish and wildlife habitat. Forested ecosystems are under pressure in the U.S. from a number of non-native insects and pathogens and from deviations from natural fire regimes (The Heinz Center, 2002). They also are becoming increasingly fragmented by urbanization and other human activities (Noss and Cooperrider, 1994).

Under its statutory programs, EPA has particularly focused on the effects of air pollution on forest ecosystems, including the effects of acid rain on forests and forest streams. Such impacts might affect not only the health and productivity of trees, but also biodiversity in forest ecosystems (Barker and Tingey, 1992). Under the Clean Air Act, EPA must promulgate secondary standards for criteria air pollutants that present unreasonable risks to plants, animals, and visibility. EPA also has statutory authority to control the effects of forest management practices on aquatic communities; safe use of herbicides and pesticides in forest systems; and significant federal activities in forested ecosystems subject to EPA's review under NEPA.

Forests are possibly the best monitored of the six ecosystem types in this report. The Forest Service has long monitored standing timber volume and production, as well as damage from fire and pests, in its Forest Inventory and Analysis (FIA) program (Smith, et al., 2001). This program relies on probability sampling to ensure that the results are statistically representative, and there is complete long-term national coverage. This results in two Category 1 indicators relating to forest extent and one to biotic condition. In the early 1990s, the Forest Service in collaboration with EPA's Environmental Monitoring and Assessment Program (EMAP) developed the Forest Health Monitoring (FHM) program to monitor additional indicators of the ecological condition of forests (see Stolte, et al., 2002), also using a probability design. Over the course of the 1990s, forests in a growing number of states were sampled in the FHM program, and many of the FHM indicators were merged into the FIA program in 1999. Although data on these indicators are now being collected in 47 states, with all 50 expected to be covered by 2005, at the time this report was being prepared, coverage was not yet sufficiently complete for these to reach Category 1 status.

[6]The concept of an ecosystem, while extremely useful and relevant, is a somewhat vague classification for purposes of environmental monitoring. See O'Neill, et al. (1986); Turner (1989); Suter (1993), pp. 275-308; and Knight and Landres (1998) for highly relevant discussions.

Exhibit 5-4: Forest Indicators

Essential Ecological Attribute	Indicators	Category		Source
Landscape Condition		1	2	
Extent of Ecological System/ Habitat Types	Extent of forest area, ownership, and management	■		USDA
	Extent of area by forest type	■		USDA
Landscape Composition	Forest age class		■	USDA
Landscape Pattern/Structure	Forest pattern and fragmentation		■	USDA
Biotic Condition				
Ecosystems and Communities	At-risk native forest species		■	NatureServe
Species and Populations	Populations of representative forest species		■	NatureServe
Organism Condition	Forest disturbance: fire, insects, and disease	■		USDA
	Tree condition		■	USDA
	Ozone injury to trees		■	USDA
Ecological Processes				
Energy Flow				
Material Flow	Carbon storage		■	USDA
Chemical & Physical Characteristics				
Nutrient Concentrations	Nitrate in farmlands, forested, and urban streams and ground water		■	DOI
Other Chemical Parameters	Wet sulfate deposition		■	EPA
	Wet nitrogen deposition		■	EPA
Trace Organic and Inorganic Chemicals				
Physical Parameters	Soil compaction		■	USDA
Hydrology and Geomorphology				
Surface and Ground Water Flows	Changing streamflows	■		DOI
Dynamic Structural Conditions				
Sediment and Material Transport	Soil erosion		■	USDA
Natural Disturbance Regimes				
Frequency	Processes beyond the range of historic variation		■	USDA
Extent				
Duration				

Many of the indicators monitored by the FIA and FHM (Smith, et al., 2001) were included in the Heinz report (2002) and formed the original core of this chapter. As this chapter was being completed, however, the Forest Service published its *Final Draft National Report on Sustainable Forests–2003* (USDA, FS, 2002) under the Montreal Process. Several of the indicators contained in this 2002 report (all Category 2) were included in this chapter to demonstrate the kinds of data that will be available nationwide for a range of the forest EEAs as the FIA achieves data collection and analysis on a national basis. Data for several of these indicators (e.g., air quality, atmospheric deposition, and the chemistry and biology of forest streams) are contributed by national monitoring programs operated by other government and private sector organizations.

The forest indicators used in this report are displayed in Exhibit 5-4, grouped according to the EEAs. Some indicators relating to the EEAs of forest landscape condition, the chemical and physical attributes of forest streams, and the hydrology of forest watersheds are discussed in the chapters on Cleaner Air, Purer Water, and Better Protected Land, because they also relate to questions about those media. This section briefly summarizes the data for these indicators as they relate to the ecological condition of forests. This section then introduces additional indicators that relate to the EEAs of forest landscape condition, biotic condition, ecological processes, physical condition of forest soils, and natural disturbances in forests.

The following indicators presented in the previous chapters relate to the ecological condition of forests:

- The indicator *Extent of Forest Area, Ownership, and Management* (Chapter 3, Better Protected Land), is important for assessing trends in how forests are managed and protected. Forested ecosystems cover some 749 million acres in the U.S., or about one-third of the total land area. While approximately 25 percent lower than the pre-settlement acreage in the 1600s, the total acreage has held steady for the past century, although regional and local patterns have changed (USDA, FS, April 2001). Since the 1950s, forest land has increased by 10 million acres in the Northeast and North Central states, and decreased by 11 million acres in the Southeast (USDA, FS, April 2001).

  About 55 percent of all U.S. forests are in private ownership, with 83 percent of forests in the East being privately held (USDA, FS, 2002). About 9 percent of forest lands are managed by private industry to produce timber. Although 503 million acres of forests are classified as "timberland," the rest receive less intensive management. Harvest on public lands declined nearly 50 percent from 1986 to 2 billion cubic feet per year in 2001, but increased on private land by 1 billion cubic feet per year, to 14 billion cubic feet per year during the same period (USDA, FS, 2002). About 38 percent of harvesting is by clearcut, mostly in the South (USDA, FS, 2002). About 76 million acres of forests are "reserved" and managed as national parks or wilderness areas, an almost threefold increase since 1953 (USDA, FS, 2002). Much of the protected forest in the West is in stands more than 100 years old.

- The indicator *Nitrate in Farmland, Forested, and Urban Streams and Ground Water* (Chapter 2, Purer Water) is important for tracking the loss of nitrate from forested watersheds, which often indicates the effects of acid rain or insect infestation. In 36 forested streams monitored by the National Water Quality Assessment (NAWQA) program, almost 50 percent had concentrations of nitrate less than 0.1 parts per million; 75 percent had concentration of less than 0.5 ppm; and only one had a concentration of more than 1.0 ppm. By comparison, of 107 agricultural watersheds, almost half of the streams had nitrate concentrations greater than 2.0 ppm.

- According to the indicator *Deposition–Wet Sulfate and Wet Nitrogen* (Chapter 1, Cleaner Air), wet sulfate deposition decreased substantially throughout the Midwest and Northeast between 1989-1991 and 1999-2001 (Chapter 1, Cleaner Air). By 2001, wet sulfate deposition had decreased by more than 8 kilograms per hectare per year (kg/ha/yr) from 30-40 kg/ha/yr in 1990 in much of the Ohio River Valley and northeastern U.S. The greatest reductions occurred in the mid-Appalachian region. Wet nitrate deposition levels remained relatively unchanged in most areas during the same period and even increased up to 3 kg/ha in the Plains, eastern North Carolina, and southern California.

  Using National Atmospheric Deposition Program data, a USDA report on sustainable forests observed that annual wet sulfate deposition decreased significantly between 1994 and 2000, especially in the North and South Resource Planning Act (RPA) regions, where deposition was the highest. Nitrate deposition rates were lowest in the Pacific and Rocky Mountain RPAs, where approximately 84 percent of the regions experienced deposition rates of less than 4.7 kg/ha/yr (4.2 pounds per acre per year). Only 2 percent of the sites in the eastern U.S. received less than that amount (USDA, FS, 2002).

- The indicator *Changing Stream Flows* (Chapter 2, Purer Water) addresses altered stream flow and timing, which are critical aspects of hydrology in forest streams. Low flows define the smallest area available to stream biota during the year, and high flows shape the stream channel and clear silt and debris from the stream. Some fish depend on high flows for spawning, and the timing of the high and low flows also can influence many ecological processes. Changes in flow can be caused by dams, water withdrawal, and changes in land use and climate. This indicator reveals that 10 percent of predominantly forested watersheds showed decreased minimum flow rates during the period 1940 through 2000 compared to the period before 1940, while 25 percent had increased minimum flow rates (USDA, FS, 2002). Five percent of the watersheds had lower maximum flow rates, and 25 percent had higher maximum flow rates compared to the earlier period. There were no obvious trends in maximum flow rates in the decades since 1940, but minimum flow rates increased over the period. Increased flows were generally found in the East, but decreased flows were found in the West.

The other 12 forest indicators in Exhibit 5-4, described on the following pages, appear for the first time in this report in this chapter. Most of these indicators are from the *Final Draft National Report on Sustainable Forests-2003* (USDA, FS,2002) which became available after The Heinz Center report went to press. All are Category 2 indicators because the data are not yet available for the entire country.

Indicator | Extent of area by forest type - Category I

Trends in the distribution of forest types ultimately control the different types of communities that they support. The data for this indicator were collected by the FIA program, which currently updates the assessment data every 5 years. This indicator compares current conditions to those in 1977.

What the Data Show

Oak-hickory forest is the most common forest type in the U.S., covering 132 million acres—an increase of 18 percent since 1977 (Exhibit 5-5). Maple-beech-birch forest covers 55 million acres and has increased 42 percent since 1977. Pine forest of various types covers 115 million acres; spruce-birch forests cover 61 million acres (mostly in Alaska); and Douglas fir covers 40 million acres, mostly in the Pacific Northwest. Mixed forests (e.g., oak-pine and oak-gum-cypress) cover 64 million acres, mostly in the South (USDA, FS, 2002).

In the East, longleaf-slash pine and lowland hardwoods (elm-ash-cottonwood and oak-gum-cypress) had the largest decreases in acreage (12 million and 17 million acres, respectively). In the West, hemlock-sitka spruce, ponderosa pine, and lodgepole pine decreased the most (by 9 million, 8 million, and 6 million acres, respectively). In both regions, "non-stocked" land, on which trees have been cut but that has not yet regrown as forest, has declined steadily.

Indicator Gaps and Limitations

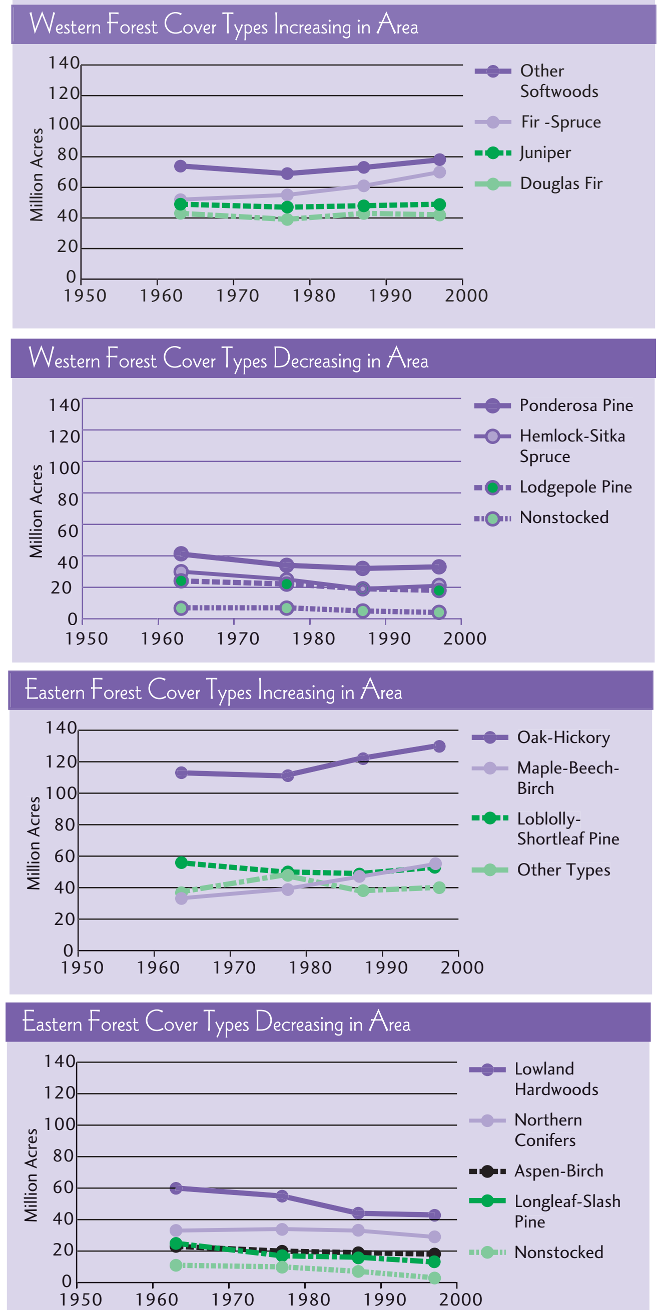
Limitations of this indicator include the following:

- Since the late 1940s, field data on species composition have been collected on a probability sample of 450,000 sites, nationwide (Smith, et al., 2001). The resulting estimates of area by forest type have an uncertainty of 3 to 10 percent per million acres of area sampled (The Heinz Center, 2002).
- The data do not include information on private lands that are legally reserved from harvest, such as lands held by private groups for conservation purposes. Other forest lands are at times reserved from harvest because of administrative or other restrictions. Data on these lands would provide a more complete picture of U.S. forest lands.

Data Source

The data source for this indicator was *Forest Resources of the United States*, 1997, Smith, et al., 2001. (See Appendix B, page B-36, for more information.)

Exhibit 5-5: Forest types in the United States, 1963-1997



Coverage: All 50 states.

Source: The Heinz Center. *The State of the Nations Ecosystems.* 2002. Data from the USDA, Forest Service.

Indicator

Forest age class - Category 2

Maintaining forest cover with a wide age range and a variety of successional stages sustains habitats for a variety of forest-dependent species and provides for the sustainable yield of a range of forest products. This indicator reports the percentage of forest area, with stands in each of several age classes.[7]

What the Data Show

In the eastern U.S., 35 percent of forests classified as "timberlands" are more than 60 years old, and 10 percent are more than 100 years old; in the West, the corresponding numbers are 70 percent and 35 percent, respectively (Exhibit 5-6). Softwood age distributions are skewed slightly toward younger age classes due to their management for timber. Hardwoods have a more normal distribution, with a peak in the 40 to 79 year age class, reflecting maturing second and third growth forests in the East. Stands averaging 0 to 5 inches and those over 11 inches are increasing, while intermediate stands in the 6 to 10 inch range are decreasing, indicating a rise in selective harvesting in the U.S. (USDA, FS, 2002).

Indicator Gaps and Limitations

Data for national parks and wilderness areas and other forested land are not available at this time, but will be in the future (The Heinz Center, 2002).

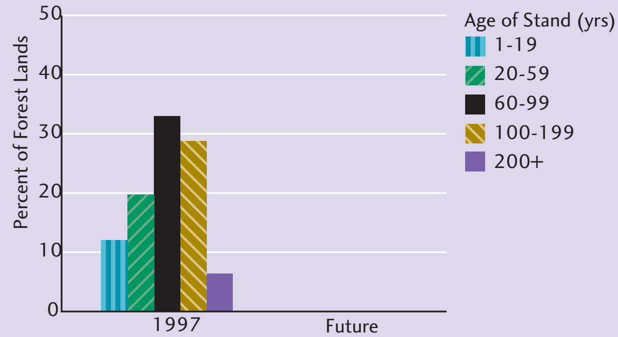
Data Source

The data source for this indicator was *Forest Resources of the United States, 1997,* Smith, et al., 2001. (See Appendix B, page B-36, for more information.)

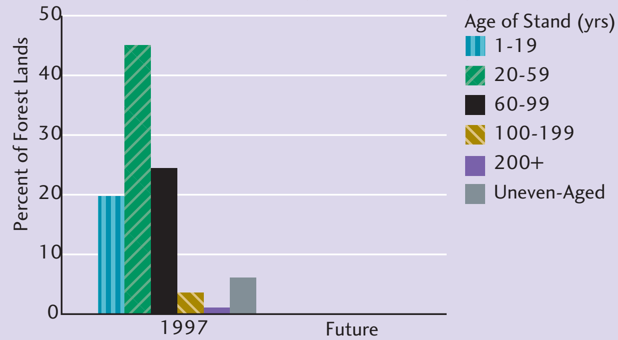
Exhibit 5-6: Forest age class, 1997

Data Not Adequate for Reporting on Forest Lands Other Than Those Classified as Timberlands

Partial Indicator Data: West (Timberlands Only)



Partial Indicator Data: East (Timberlands Only)



Coverage: all 50 states (timberlands only.)

Note: "Timberlands" is a USDA Forest Service designation for lands that grow at least 20 cubic feet of wood per acre per year, which is considered be sufficient to support commercial harvest under current economic conditions. Lands on which harvest is prohibited by statute are not included as "timberlands." Note also that the term "uneven-age" is being phased out; such stands are composed of intermingled trees that differ considerably in age.

Source: The Heinz Center. *The State of the Nation's Ecosystems.* 2002. Data from the USDA, Forest Service.

[7]Age class is defined by the mean age of the dominant or codominant crowns in the upper layer of the tree canopy.

Indicator — Forest pattern and fragmentation - Category 2

Forest pattern and fragmentation affect the plant and animal species that live in forests. Large blocks of contiguous forest support interior forest species. Partial forest cover creates forest edge habitat, which supports birds and other animals that nest in forests but forage in nearby fields (Ritters, et al., 2002). Fragmentation also creates areas that concentrate airborne nutrients and pollutants by increasing the amount of unprotected forest edge (Weathers, et al., 2001). This indicator captures some of these features.

What the Data Show

Fragmentation in forests in the U.S. is significant. Based on 1992 data (The Heinz Center, 2002), two-thirds of all points within forests were surrounded by land that was at least 90 percent forest in their "immediate neighborhood" (i.e., a radius of 250 feet) (Exhibit 5-7). However, only one-fourth of the points within forests were surrounded by land that was at least 90 percent forest within their "larger neighborhood" (i.e., to a radius of 2.5 miles) (The Heinz Center, 2002). Approximately half of the fragmentation consists of "holes" in otherwise continuous forest cover. About three-quarters of all forest land is found in or near the boundaries of these large (greater than 5,000 hectares), but heavily fragmented, forest patches (Ritters, et al., 2002). In short, most forest is near other forest, and "holes" in forest cover caused by development, agriculture, harvesting, etc., tend to be isolated from each other.

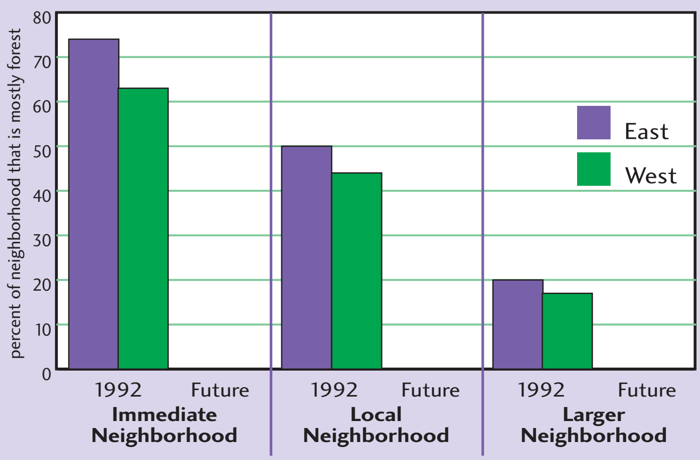
Indicator Gaps and Limitations

Although this indicator was calculated for the conterminous U.S., it has been categorized as a Category 2 indicator because it is only one of many potentially important fragmentation indicators. The exact impact of the amount and type of fragmentation on biotic structure and ecological processes is poorly known, and is likely to vary from one species and process to another (Ritters, et al., 2002). The FHM program is developing additional landscape fragmentation indicators, but the data have not been fully evaluated as this report was being finalized.

Data Sources

The data source for this indicator was *Forest Health Monitoring National Technical Report, 1991 to 1999*, U.S. Department of Agriculture, Forest Service, Southern Research Station, 2002; and *Fragmentation of Continental United States Forests*, Ritters, et al., 2002. (See Appendix B, page B-37, for more information.)

Exhibit 5-7: Forest cover and neighborhood size, 1992



Immediate neighborhood: land within a radius of about 250 ft from each forest point.
Local neighborhood: land within a radius of about 1/4 mile from each forest point.
Larger neighborhood: land within a radius of about 2 1/2 miles from each forest point
Mostly forest: land that is at least 90% forested (less than 10% nonforest)

Coverage: lower 48 states
Source: The Heinz Center. *The State of the Nation's Ecosystems.* 2002. Data from the Multi-Resolution Characterization Consortium and the USDA, Forest Service.

Indicator At-risk native forest species - Category 2

Species richness is considered to be an important indicator of ecological condition by both the National Research Council (2000) and the Science Advisory Board (2002). Although the role of species richness in maintaining a stable ecosystem is debated, greater species richness (i.e., greater number of species) is generally accepted as desirable. Species richness could be altered by air pollution, fragmentation, and forest disturbance by fire, insects, or disease.

What the Data Show

Based on an assessment of 12 factors, NatureServe and its member programs in the Natural Heritage program determined that 5 percent of forest animal species are imperiled, 3.5 percent are critically imperiled, and 1.5 percent are or might be extinct (The Heinz Center, 2002) (Exhibit 5-8). This indicator includes reports on mammals, amphibians, grasshoppers, and butterflies; too little is known about other groups, including plants, to assign risk categories. NatureServe data reveal that of the 1,642 species of terrestrial animals associated with forests, 88 percent still occupy their full historical geographic range on a state-by-state basis (USDA, FS, 2002).

The Natural Heritage Program uses standard ranking criteria and definitions, making the ranks comparable across groups. This means that "imperiled" has the same basic meaning whether applied to a salamander, a moss, or a forest community. Ranking is a qualitative process, however, taking into account several factors that function as guidelines rather than arithmetic rules. The ranker's overall knowledge of the element allows him or her to weigh each factor in relation to the others and to consider all pertinent information for a particular element. The factors considered in ranking species include population size, range extent and area of occupancy, short- and long-term trends in the foregoing factors, threats, and fragility (Stein, 2002).

The information gathered by Natural Heritage data centers also provides support for official designations of endangered or threatened species. However, because Natural Heritage lists of vulnerable species and official lists of endangered or threatened species have different criteria, evidence requirements, purposes, and taxonomic coverage, they normally do not coincide completely with the official designations of "rare and endangered" species.

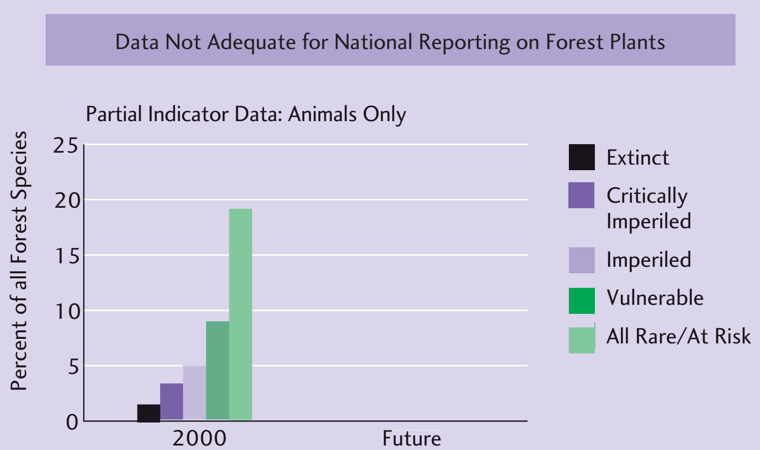
Indicator Gaps and Limitations

The data for this indicator are not from a site-based monitoring program, but rather from a census approach that focuses on the location and distribution of at-risk species. Determining whether species are naturally rare or have been depleted is currently not possible. It is not clear that trends can be quantified with any precision.

Data Source

The data source for this indicator was *The State of the Nation's Ecosystems,* The Heinz Center, 2002, using data from the NatureServe Explorer Database. (See Appendix B, page B-37, for more information.)

Exhibit 5-8: At-risk native forest species, by risk category, 2000



Coverage: all 50 states.

Source: The Heinz Center. *The State of the Nation's Ecosystems.* 2002. Data from NatureServe and its Natural Heritage member programs.

Indicator | Populations of representative species - Category 2

The abundance of species representative of particular forest types is a more sensitive and less dramatic measure of ecological condition than species richness alone. Species richness reflects the net number of species invading an area and species going extinct, whereas species abundance also includes the numbers of individuals in each species (USDA, FS, 2002). The FHM program has collected abundance data on bird and tree species.

What the Data Show

Between 1966 and 1979, 21 percent of bird species associated with forests experienced population declines. This figure rose to 26 percent between 1980 and 2000 (USDA, FS, 2002). Areas with the greatest population declines were along the coasts and in the Appalachians. Between 1966 and 2000, 26 percent of bird species associated with forests showed population increases.

In the majority of tree species groups, the number of trees with trunk diameters greater than 1 foot increased by more than 50 percent between 1970 and 2002, indicating a more abundant community of older trees (USDA, FS, 2002) (Exhibit 5-9).

Indicator Gaps and Limitations

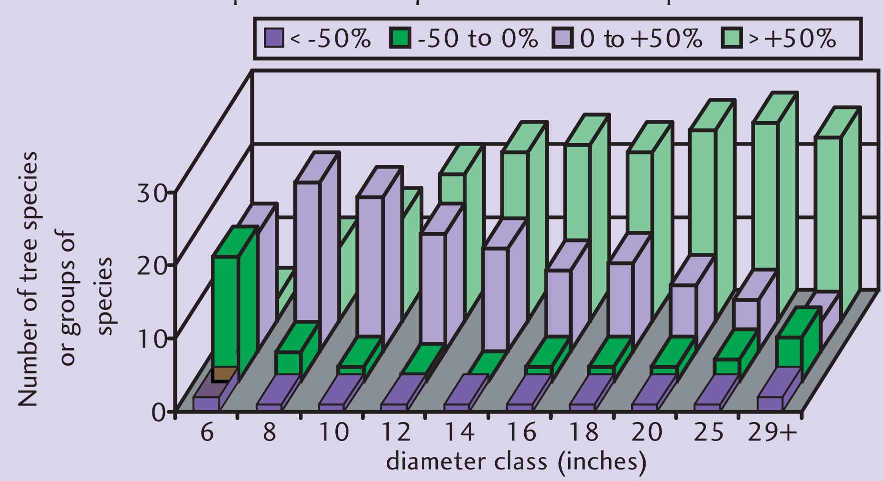
Several limitations are associated with this indicator:

- Population data are available only for birds and trees. Data for big game are reported by the states, but generally very few systematic measures of animal population density exist.
- The data from the Breeding Bird Survey (BBS) are based on a volunteer observer program and might not be statistically reliable.

Data Sources

The data sources for this indicator were the Breeding Bird Survey, U.S. Geologic Survey (1966-2000); and U.S. Department of Agriculture, Forest Service. *Draft Resource Planning and Assessment Tables*, 2002; and *National Report on Sustainable Forests-2003, Final Draft*, U.S. Department of Agriculture, Forest Service, 2002. (See Appendix B, page B-38, for more information.)

Exhibit 5-9: Populations of representative forest species, 1970-2002



Coverage: 37 states.

Source: USDA, Forest Service. Draft Resource Planning Act Assessment Tables. May 3, 2002 (updated August 12, 2002). (September 2002; *http://www.ncrs.fs.fed.us/4801/FIADB/rpa_tabler/Draft_RPA_2002_Forest_Resource_Tables.pdf.*)

Indicator Forest disturbance: fire, insects, and disease - Category 1

Fires, insects, and disease often occur naturally in forests. Their impact on forest ecosystems can be influenced by their interaction with other variables such as management decisions, air pollutants, and variations in climate. For example, trees weakened by pollutants might be more susceptible to attack by pathogens. When ecological processes are altered beyond a critical threshold, significant changes to forest conditions might result.

What the Data Show

Wildfire acreage has declined from a peak of more than 50 million acres per year in the 1930s to 2 to 7 million acres per year, largely due to fire suppression policies (The Heinz Center, 2002).[8] However, there has been a slight increase in fires in national forests in recent decades, with 8.4 million acres burned in 2000 (Exhibit 5-10).

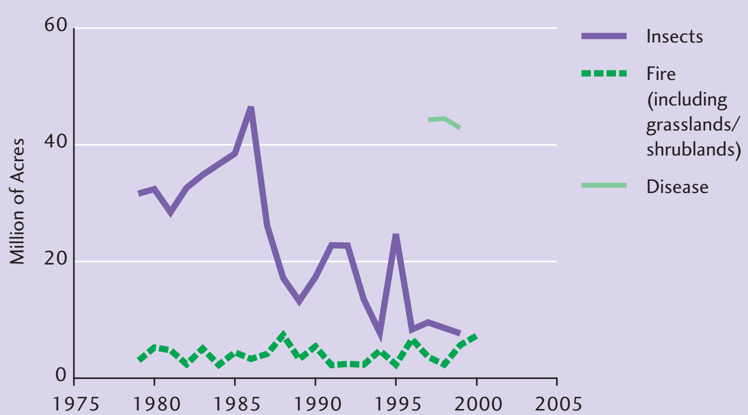
Insect damage fluctuates from year to year, mostly as a result of population cycles of the gypsy moth and southern pine beetle, affecting between 8 and 46 million acres per year. Data for two major parasites, fusiform rust and mistletoe, are available only for the past several years, but the total acreage affected is 43 to 44 million acres (The Heinz Center, 2002).

Indicator Gaps and Limitations

Limitations of this indicator include the following:

- This indicator does not distinguish between forest fires, other wildfires, and prescribed burns. It also does not track the intensity of the fires.
- Data are not available on forests affected by diseases other than those listed above.
- Some insects can cause widespread damage before it is apparent from aerial surveys.

Exhibit 5-10: Forest disturbance: fire, insects, and disease, 1979-2000



Insects: gypsy moth, spruce budworm, southern pine beetle, mountain pine beetle, western spruce budworm (all but the gypsy moth are native to the United States.)

Diseases: fusiform rust, dwarf mistletoe

Coverage: all 50 states

Note: Data are not limited to national forests.

Source: The Heinz Center. *The State of the Nation's Ecosystems.* 2002. Data from the USDA, Forest Service Health Protection/Forest Health Monitoring Program (insects, disease) and the National Forest System (fire).

Data Sources

The data sources for this indicator were *The State of the Nation's Ecosystems,* The Heinz Center, 2002, using data from *Western National Forests: Nearby communities are increasingly threatened by catastrophic wildfires,* U.S. General Accounting Office, 1999; *Forest Health Monitoring National Technical Report, 1991-1999,* U.S. Department of Agriculture, Forest Service, Southern Research Station, 2002; and National Fire Statistics, the National Interagency Fire Center, (See Appendix B, page B-38, for more information.)

[8]These data include wildfires in grasslands and shrublands.

Indicator Tree condition - Category 2

Changes in tree condition reflect the sum total of factors acting on the tree, including stress due to pollutants, climate, nutrient status, soil condition, and disease. This indicator (called "diminished biological components" in USDA, FS, 2002), reports on the percentage of trees in each region of the conterminous U.S. states that exhibit significant changes in three measures: mortality volume, crown condition, and the area in fire Current Condition Class 3. A Resource Planning Act region (shown in Exhibit 5-11) was considered to have poor tree condition (designated as diminished biological components in the exhibit) if (1) average annual mortality volume was more than 60 percent of gross annual growth volume, or (2) the ZB-index, an indicator of crown condition, was increasing at a rate of 0.015 or more per year, or (3) more than half of the forest area was in fire Current Condition Class 3. Fire condition Class 3 represents a major deviation from the ecological conditions compatible with historic fire regimes and might require management activities such as harvesting and replanting to restore the historic fire regime.

What the Data Show

According to the data for this indicator, 20 percent of forests in the U.S. were observed to exhibit poor tree condition, 40.9 percent were in fair or good condition, and 38.8 percent had no or insufficient data (USDA, FS, 2002) (Exhibit 5-11). Mortality was highest in the Pacific Northwest and northern Minnesota, and a large portion of these forests was in fire Current Condition Class 3, indicating that mortality might be producing a high fuel load. The South and Rocky Mountain regions had the smallest areas of poor tree condition, but more than half of those areas had insufficient data or no data at all.

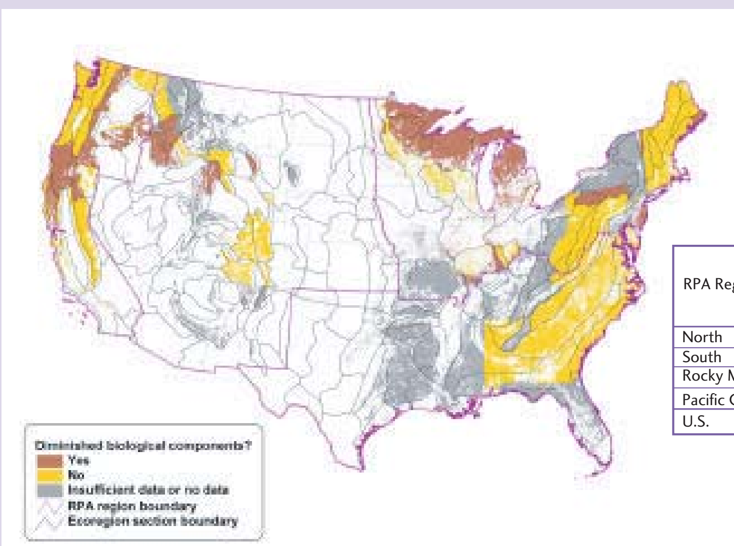
Indicator Gaps and Limitations

The data used to calculate this indicator were available at the time for only 32 states; more than half of the South and Rocky Mountain regions had insufficient or no data at all.

Data Sources

The data sources for this indicator were *Forest Health Monitoring National Technical Report,* 1991-1999, U.S. Department of Agriculture, Forest Service, Southern Research Station, 2002, and *National Report on Sustainable Forests-2003, Final Draft*, U.S. Department of Agriculture, Forest Service, 2002. (See Appendix B, page B-39, for more information.)

Exhibit 5-11: Tree condition, 1990-1999



RPA Region	Diminished Biological Components? Yes	No	No or Insufficient Data
	percent		
North	33.1	37.1	29.8
South	0.0	43.1	56.9
Rocky Mtn.	18.5	29.2	52.3
Pacific Coast	40.5	59.5	0.0
U.S.	20.3	40.9	38.8

Coverage: 32 states.

Forest area having diminished biological components that may indicate changes in fundamental ecological processes and/or ecological continuity. Percentages based on forest area in conterminus 48 States.

Source: Conkling, B., et al. *Forest Health Monitoring National Technical Report 1991-1999.* 2002.

Indicator Ozone injury to trees - Category 2

Ozone injury to trees can be diagnosed by examination of plant leaves (Skelly, et al., 1987; Bennet, et al., 1994). Foliar injury is the first visible sign of injury of plants from ozone exposure and indicates impairment of physiological processes in the leaves.

What the Data Show

Little or no ozone injury was reported at 97 percent of Pacific Coast sites and 100 percent of Rocky Mountain sites (Exhibit 5-12). In the North and South regions, however, 23 percent of biomonitoring sites showed at least low levels of injury, with severe levels observed at about 5 percent of the plots (USDA, FS, 2002).

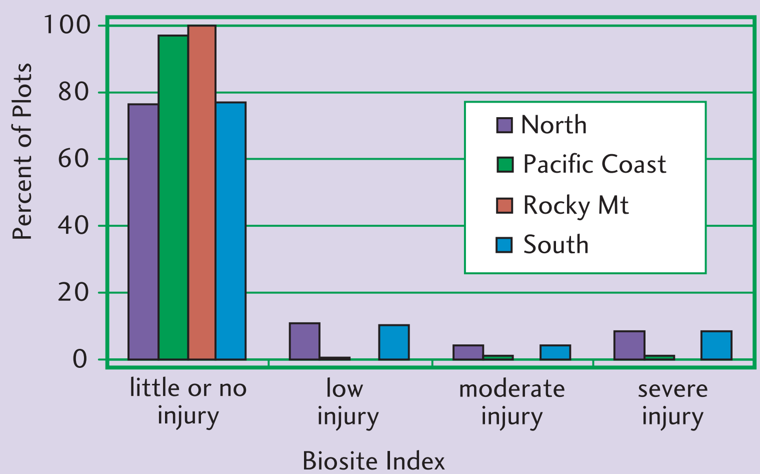
Indicator Gaps and Limitations

- Any further injury to the plant (beyond injury to the leaves) requires that ozone penetrate through the stomata into the leaf interior, which is regulated by a variety of environmental processes; some plants that show foliar damage show no further damage, and some plants show damage without concurrent signs of leaf damage (EPA, ORD, July 1996).
- Biomonitoring site data were available for only 32 states at the time the data for this indicator were analyzed.

Data Sources

The data sources for this indicator were the Forest Health Monitoring Program, U.S. Department of Agriculture (1991-2000) and *National Report on Sustainable Forests-2003, Final Draft*, U.S. Department of Agriculture, Forest Service, 2002. (See Appendix B, page B-39, for more information.)

Exhibit 5-12: Ozone injury to trees, 1994-2000



Coverage: 32 states.

Source: USDA, Forest Service. *National Report on Sustainable Forests - 2003. Final Draft.* 2002.

Indicator Carbon storage - Category 2

As a result of photosynthesis, carbon is stored in forests for a period of time in a variety of forms before it is ultimately returned to the atmosphere through the respiration and decomposition of plants and animals. A substantial pool of carbon is stored in woody biomass (roots, trunks, and branches). Another portion eventually ends up as dead organic matter in the upper soil horizons. Carbon storage in forest biomass and forest soils is essential for stable forest ecosystems, and it reduces atmospheric concentrations of a carbon dioxide, a greenhouse gas (see Chapter 1, Cleaner Air).

What the Data Show

For the period 1953 to 1996, the average annual net storage of non-soil forest carbon pools was 175 million tonnes of carbon per year (MtC/yr). The rate of storage for the last period of record (1987-1996) declined to 135 MtC/yr (Exhibit 5-13). The decrease in sequestration in the last period is thought to be due to more accurate data, increased harvests relative to growth, and better accounting of emissions from dead wood. The Northern region is sequestering the greatest amount of carbon, followed by the Rocky Mountain region. The trend of decreasing sequestration in the South is due to the increase in harvesting relative to growth. Some of the harvested carbon is sequestered in wood products (USDA, FS, 2002).

Indicator Gaps and Limitations

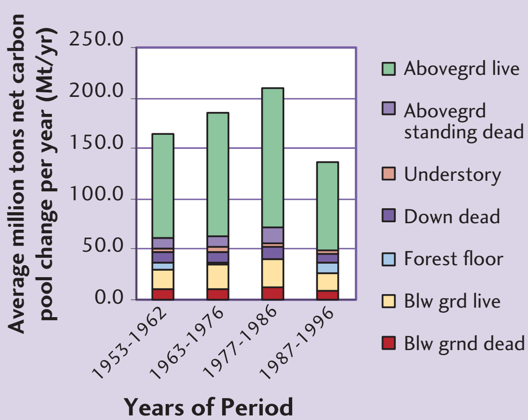
Limitations of this indicator include the following:

- The data only cover forest classified as "timberland," which excludes about one-third of U.S. forests.
- Carbon stored in soil is not included.
- Several of the carbon pools are not measured, but are estimated based on inventory-to-carbon relationships developed with information from ecological studies.

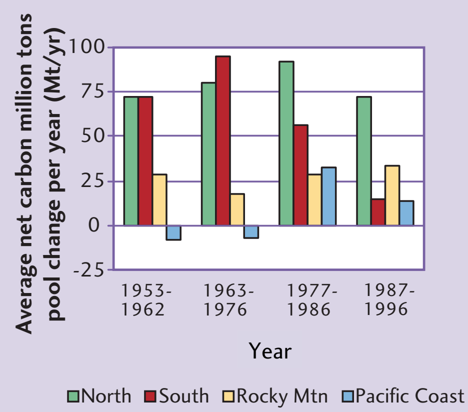
Data Sources

The data sources for this indicator were the Forest Inventory and Analysis, U.S. Department of Agriculture (1979-1995); and *National Report on Sustainable Forests, 2003, Final Draft*, U.S. Department of Agriculture, Forest Service, 2002.
(See Appendix B, page B-39, for more information.)

Exhibit 5-13: Contribution of forest ecosystems to the total global carbon budget, 1953-1996



Average annual net forest carbon change (Mt/yr), 1953-1996



Average annual net forest carbon change (Mt/yr) by region, 1953-1996

Coverage: lower 48 states.

Source: USDA, Forest Service. *National Report on Sustainable Forests - 2003. Final Draft.* 2002.

Indicator Soil compaction - Category 2

This indicator measures the extent of changes to the physical properties of forested soils resulting from forest harvesting, road construction, or other human impacts that are of sufficient magnitude to lower soil fertility or cause significant reductions in site productivity. Compaction can have a variety of negative effects on soil fertility by causing changes in both physical and chemical properties (Sutton, 1991; Fisher and Binkley, 2000). Reduction in pore space makes the soil more dense and difficult to penetrate and thus can constrain the size, reach, and extent of root systems. Reduction in soil aeration and water movement can reduce the ability of roots to absorb water, nutrients, and oxygen, resulting in shallow rooting and stunted trees. Destruction of soil structure can limit water infiltration and increase rates of runoff and soil loss from erosion.

What the Data Show

Soil compaction is primarily a local phenomenon. More than 86 percent of the plots measured showed less than 5 percent of the plot area exhibitng of soil compaction (Exhibit 5-14) (USDA, FS, 2003). Only a small fraction of plots (1.6 percent) showed compaction on more than 50 percent of the plot.

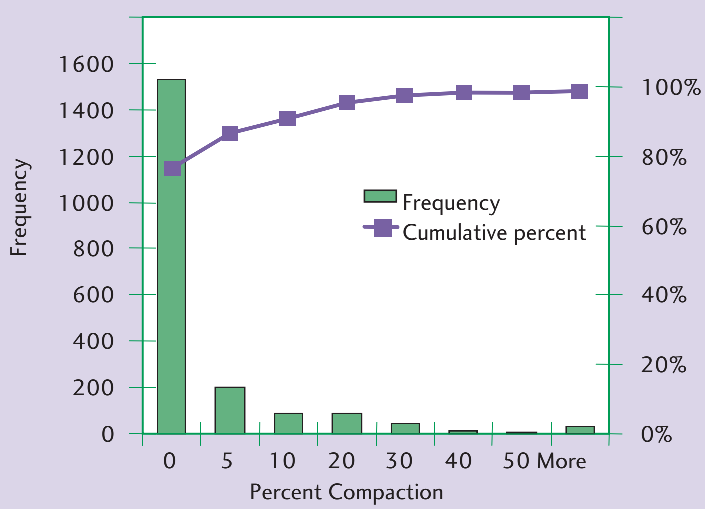
Indicator Gaps and Limitations

Soil physical properties (e.g., bulk density) are not conventionally monitored in a way that facilitates national reporting, and the current approach relies heavily on visual inspection and the State Soil Geographic Database (STATSGO) state soil maps (USDA, FS, 2003). No measurements were made of the degree or intensity of compaction. Physical disturbances that are not readily visible from the surface might be under-reported. Therefore the national maps thus far are only indicative of the *potential* for soil compaction on a regional basis. The FIA program has begun monitoring actual soil physical properties at the FIA sites, to be used in conjunction with the current method, but the data were not available nationally for development of the indicator in 2002 (USDA, FS, 2003).

Data Source

The data sources for this indicator were the Forest Health Monitoring Program, U.S. Department of Agriculture (1999-2000); and State Soil Geographic Database (STATSGO) state soil maps. (See Appendix B, page B-40, for more information.)

Exhibit 5-14: Frequency distribution of percent of plot area exhibiting evidence of surface compaction reported on Forest Health Monitoring (FHM) Program plots, 1999-2000



Coverage: 37 states.

Source: USDA, Forest Service. *National Report on Sustainable Forests-2003*. 2003.

Indicator **Soil erosion - Category 2**

Erosion is a term used to describe various mechanisms that wear away the land surface. Soil erosion is caused naturally by running water, wind, ice, and other geologic processes, but forest harvesting and road construction can increase erosion beyond natural levels. Erosion in excess of soil formation decreases the long-term productivity of forest systems and contributes to siltation of streams, lakes, and reservoirs. The Water Erosion Prediction Project (WEPP) model is commonly used in conjunction with the STATSGO state soil maps to estimate and predict the amount of soil loss based on several factors influencing erosion (Liu, et al., 1997).

What the Data Show

Modeled erosion rates on undisturbed forest lands were less than 0.05 ton per acre per year, on nearly 90 percent of the measured plots, compared to 3.1 tons per acre per year in agricultural ecosystems (USDA, FS, 2003) (Exhibit 5-15). Exposed mineral soil is a substantial contributor to erosion in the regions of the country sampled, and about 65 percent of the measured forest plots showed bare soil on less than five percent of the plot.

Indicator Gaps and Limitations

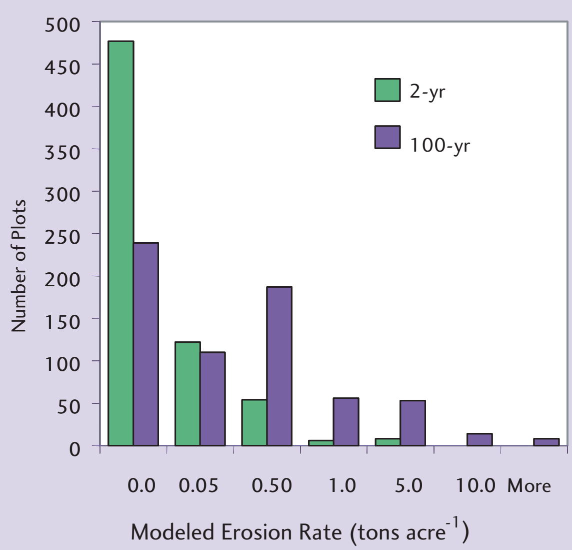
Limitations of this indicator include the following:

- The modeling approach (WEPP) was originally designed for agricultural systems. It might overestimate erosion from well-managed forest plots and underestimate erosion on plots that have been harvested and mechanically prepared (USDA, FS, 2003).
- The erosion indicator was calculated for only 37 states by 2002.

Data Sources

The data sources for this indicator were the Forest Health Monitoring Program, U.S. Department of Agriculture (1991-2000); and State Soil Geographic Database (STATSGO) state soil maps. (See Appendix B, page B-40, for more information.)

Exhibit 5-15: Frequency distribution for modeled erosion rates on Forest Health Monitoring (FHM) Program plots (1999-2000) following a 2-year (average) and 100-year storm event



Coverage: 23 states, excluding Alaska and Hawaii

Note: As an initial step in this analysis, model runs assume an undisturbed forest.

Source: USDA, Forest Service. *National Report on Sustainable Forests-2003*. 2003.

Indicator Processes beyond the range of historic variation - Category 2

The Forest Health Monitoring (FHM) program (USDA, FS, 2002) provided one of the few examples of an indicator that considers the essential ecological attribute of natural disturbance. The FHM program analyzed Forest Inventory and Analysis (FIA) data on climatic events, fire frequency, and insect and disease outbreaks between 1996 and 2000. These data were compared to anecdotal data from 1800 to 1850 to determine whether recent patterns in such incidents were beyond the range of historic variation. The FIA data were also compared to data from between 1978 and 1995 to determine if they were beyond the range of "recent" variation.

What the Data Show

A number of incidents were determined to be outside the range of recent variation in natural disturbance:

- El Niño during 1997 to 2000.
- A 1998 ice storm in the Northeast.
- Total area burned in the West during 1996, 1998, and 2000, and the total area burned nationwide in 2000.
- Outbreaks of spruce beetle in 1996, spruce budworm in 1997, and southern pine beetle in 2000.

Indicator Gaps and Limitations

Several limitations are associated with this indicator:

- This analysis was limited by the lack of metric data (actual measurements) available to describe conditions from 1800 to 1850.
- A relatively complete data set for major forest insects and diseases exists for the period 1979 to 2000, but these data are too recent for establishing a historical baseline.

Data Sources

The data sources for this indicator were the Forest Inventory and Analysis, U.S. Department of Agriculture (1979-1995); and *National Report on Sustainable Forests-2003-Final Draft,* U.S. Department of Agriculture, Forest Service, 2002. (See Appendix B, page B-41, for more information.)

Summary: The Ecological Condition of Forests

The available data are not, at this point, sufficient to track the progress of EPA's programs as they relate to the ecological condition of forest ecosystems. When the FHM/FIA program indicators are measured nationwide and repeatedly, they will form an important baseline against which to monitor the response of forests and their associated fauna to air pollutants, climate change, and management practices that impact forest ecosystems. At this point, the results of the leaf injury indicator suggest that research and assessment of the actual effects of ozone on forest ecosystems should be continued. The increasing acreage of older forests stands and changes in forest stream hydrology might bear watching inasmuch as these factors alter responses of forest systems to air and water pollutants.

Landscape condition

The total acreage of forests has remained steady over the past century and, although the acreage of some of the types of forests have changed, none are currently at risk of being lost. Over the past 50 years, the amount of non-stocked forest has decreased, while the amount of forest with older trees has increased. Forests are highly fragmented, but most forest land exists in or near the boundaries of large tracts of forest land.

Biotic condition

Most forest-related species continue to occupy a large portion of their original range. Eleven percent of species dependent on forest land are imperiled (5.7 percent are mammals, 2.3 percent are amphibians, and 1.4 percent are birds). Twenty-five percent of forest bird species have declined since 1975 (mostly in the Southeast), 25 percent have increased (mostly in the North), and 50 percent have stayed approximately the same. These results indicate that some forest habitats may not be supporting all the species they did historically. Currently no reliable data exist on the condition of biota in forest streams nationally or regionally. Our understanding of the relationship between indicators and biological conservation strategies remains weak (Lindenmeyer, et al., 2000).

According to available data, 20 percent of forests monitored in the U.S. were observed to exhibit poor tree condition, and 23 percent of biomonitoring plots in the eastern U.S. showed more than a small amount of ozone impact on plant leaves. Severe ozone damage to leaves was observed at 5 percent of the plots.

Ecological Processes

Annual rates of carbon storage in timberland increased over the three decades between 1953 and 1986 due to increasing age of timber stands and growth of woodlots on what was once farmland. However, annual storage declined in the decade 1987 to 1996, in part because of harvesting in Southeastern forests.

Chemical and physical characteristics

Nitrate loss from most forests does not appear to be resulting in high nitrate concentrations in forest streams, but few streams are monitored in areas where nitrate deposition is high (the East), and the baseline is too short to determine whether there are trends in the data.

Hydrology and geomorphology

With respect to forest streams, there has been a tendency toward decreased minimum flow rates in 10 percent of forest streams during the period 1940 through 2000 compared to pre-1940, while 25 percent of forest streams had increased minimum flow rates. Five percent of the watersheds had lower maximum flow rates and 25 percent had higher maximum flow rates. There were no obvious trends in maximum flow rates in the decades since 1940, but there was an increase in the minimum flow rates during that period. Increased flows were generally found in the East, and decreased flows were found in the West. Soil compaction is a problem on more than 10 percent of the plots in only 10 percent of monitored forest land.

Natural disturbance regimes

A number of events were determined to be outside the range of recent variation in natural disturbance, including two El Niño events, a severe ice storm in the Northeast, total area burned in the West during three years and the total area burned nationwide in 2000, and several tree pest outbreaks. The ecological consequences of these events are undoubtedly significant, but have not been systematically analyzed.

Many indicators currently being evaluated by the FIA and FHM programs are not included in this section because the results were not included in the Forest Service's most recent report on sustainable forests (USDA, FS, 2002). Because most of these measurements are made in a way that allows unbiased estimates and known uncertainty bounds, the ecological condition of forests will be even better known in the coming years.

5.3 What Is the Ecological Condition of Farmlands?

Agricultural practices using high-yielding crop varieties, fertilization, irrigation, and pesticides have contributed substantially to increased food production over the past 50 years (Matson, et al., 1997). These same practices also have altered the biotic interactions in farmlands, with local, regional, and global ecological consequences (Matson, et al., 1997). This report (following The Heinz Center, 2002) defines a farmland as consisting of not only of the lands used to grow crops, but also the field borders, windbreaks, small woodlots, grassland and shrubland areas, wetlands, farmsteads, small villages, and other built-up areas within or adjacent to croplands. These land covers/uses both support agricultural production and provide habitat for a variety of wildlife species. Farmlands include lands that grow perennial and annual crops as well as lands that are used to produce forage for livestock. This definition overlaps with other ecosystems; most notably, pastures are considered croplands, but are also considered part of grassland/shrubland ecosystems.

Among ecologists concerned with ecological condition, farmlands are often referred to as "agroecosystems." EPA is interested not only in the ecological condition of farmlands, but also in their effects on adjacent ecosystems. Developing and implementing agricultural practices that integrate crop and livestock production with ecologically

Exhibit 5-16: Farmland indicators

Essential Ecological Attribute	Indicators	Category		Source
Landscape Condition		1	2	
Extent of Ecological System/Habitat Types	Extent of agricultural land uses	■		USDA
Landscape Composition	The farmland landscape	■		DOI
Landscape Structure/Pattern				
Biotic Condition				
Ecosystems and Communities				
Species and Populations				
Organism Condition				
Ecological Processes				
Energy Flow				
Material Flow				
Chemical and Physical Characteristics				
Nutrient Concentrations	Nitrate in farmland, forested, and urban streams and ground water		■	DOI
	Phosphorus in farmlands, forested and urban streams		■	DOI
Other Chemical Parameters				
Trace Organics and Inorganics	Pesticides in farmland streams and ground water		■	DOI
	Potential pesticide runoff from farm fields		■	USDA
	Pesticide leaching potential		■	USDA
	Soil quality index		■	EPA
Physical Parameters				
Hydrology and Geomorphology				
Surface and Ground Water Flows				
Dynamic Structural Conditions				
Sediment and Material Transport	Soil erosion		■	EPA
	Sediment runoff potential from croplands and pasturelands		■	USDA
Natural Disturbance Regimes				
Frequency				
Extent				
Duration				

based management practices has become the key for sustainable agriculture (NRC, 1999).

Some of the data on farmlands are available through the National Agricultural Statistics Service (NASS). Over the past 80 years, NASS has administered the USDA's program of collecting and publishing national and state agricultural statistics. NASS currently publishes more than 400 reports a year covering virtually every facet of U.S. agriculture—production and supplies of food and fiber, prices paid and received by farmers, farm labor and wages, and farm aspects of the industry. These estimates are based on a statistical area sampling frame that represents the entire land mass of the U.S. The biological indicators currently measured by NASS are primarily related to crop or animal production. However, NASS does not report on indicators of ecological condition. Physical or chemical indicators usually provide information relevant for agronomic production, but also can provide limited information on potential stressors to adjacent terrestrial and aquatic ecosystems such as soil erosion; nitrogen, phosphorus and pesticide runoff; and phosphorus and nitrate concentrations in farmland streams.

In 1990, EPA and the USDA Agricultural Research Service (ARS) undertook an interagency effort to assess the ecological condition of agroecosystems as part of the Environmental Monitoring and Assessment Program (EMAP). In 1994 and 1995, EMAP piloted a regional-scale assessment in the mid-Atlantic region (Hellkamp, et al., 2000). Some of the resulting indicators used in that pilot are included as Category 2 indicators in this report. These indicators could be measured in other regions and eventually across the nation in conjunction with the NASS annual surveys.

The farmland indicators used in this report are displayed in Exhibit 5-16, grouped according to the essential ecological attributes (EEAs). Some indicators relating to the EEAs of farmland landscape condition, the chemical and physical attributes of farmland streams, and the hydrology of farmland watersheds have been presented in the previous chapters on Better Protected Land and Purer Water, because these indicators also relate to questions about those media. Below, this section briefly summarizes the data for these indicators as they relate to the ecological condition of farmlands. The section then introduces additional indicators that relate to the EEAs of physical and chemical properties of farmland soils and the hydrology and geomorphology contributing to loss of soil from farmlands. Data are insufficient for national reporting on indicators in three of the six categories of EEAs: biotic condition, ecological processes, and natural disturbance regimes (The Heinz Center, 2002).

The following indicators presented in previous chapters relate to the ecological condition of farmlands:

- According to the indicator *Extent of Agricultural Land Uses* (Chapter 3, Better Protected Land), croplands total 377 million acres. As of 1997, Conservation Reserve Program (CRP) lands totaled 32 million acres, excluding Alaska (USDA, NRCS, 2000). Between 1982 and 1997, cropland decreased 10.4 percent, from about 421 million acres to nearly 377 million acres. Of this 44-million acre decrease, however, 32.7 million acres are now enrolled in the CRP, leaving an 11.3 million acre loss as a result of conversion of croplands to other land uses (USDA, NRCS, 2000).

  Unfortunately, there is no single, definitive, accurate estimate of the extent of cropland. Cropland is a flexible resource that is constantly being taken in and out of production. In addition, estimates of the amount of land devoted to farming differ because different programs use different methods to acquire, define, and analyze their data. For example, The Heinz Center report assesses total cropland (including pasture and hayland) as covering between 430 and 500 million acres in 1997, or about a quarter of the total land area in the U.S. (excluding Alaska). This report does not reconcile these differences, but does acknowledge that there are different estimates.

- The *Farmland Landscape* indicator (Chapter 3, Better Protected Land) describes the degree to which croplands dominate the landscape and the extent to which other land uses are intermingled (The Heinz Center, 2002). Croplands comprise about half of the larger farmland ecosystems in the East and Southeast and almost three-quarters of the farmland ecosystems in the Midwest (The Heinz Center, 2002). The remainder of the farmland ecosystems are forests in the East, wetlands in the Southeast, and both forests and wetlands in the Midwest. In the West, about 60 percent of farmland ecosystems are cropland, with grasslands and shrublands dominating the remainder in the western and northern Plains areas. Forests and grasslands/shrublands are about equal in the farmland landscape for the non-cropland area of the South Central region. In many areas of the U.S., other land cover types are almost as prevalent as croplands and can provide habitat for non-agronomic species.

- The indicator *Nitrate in Farmland, Forested, and Urban Streams and Ground Water* (Chapter 2, Purer Water) shows the loss of nitrate from agricultural watersheds, usually indicating the extent to which nitrogen fertilizer is lost or animal manure reaches streams via runoff or ground water. Sampling in areas where agriculture is the primary land use found that about 50 percent of the 52 stream sites sampled and 45 percent of the ground water wells sampled had nitrate concentrations greater than 2 ppm. About 20 percent of the ground water sites and 10 percent of the stream sites sampled had nitrate concentrations exceeding the drinking water nitrate standard of 10 ppm. These figures are much higher than the nitrate concentrations in forest streams (The Heinz Center, 2002).

- The indicator *Phosphorus in Farmland, Forested, and Urban Streams* (Chapter 2, Purer Water), shows the loss of phosphorus from agricultural watersheds, again usually indicating losses from fertilizer and animal manures. Total phosphorus concentrations in farmland streams were reported in four classes in the Heinz report: < 0.1 ppm, 0.1-0.3 ppm, 0.3-0.5 ppm, and > 0.5 ppm (The Heinz Center, 2002). EPA has set new regional criteria for phosphorous concentration, ranging from 0.023 to 0.076 ppm, to protect streams in agricultural ecosystems from eutrophication. The criteria vary according to differences in ecoregions, soil types, climate, and land use. The Heinz Center (2002) reports that about 75 percent of farmland streams had phosphorous concentrations greater than 0.1 ppm, thus exceeding any of EPA's criteria for eutrophication. Fifteen percent had phosphorous concentrations equal to or exceeding 0.5 ppm (The Heinz Center, 2002). Average phosphorous concentrations in farmland streams were similar to phosphorous concentrations measured in urban streams. As with nitrate concentrations, forest streams had lower phosphorous concentrations than farmland or urban streams.

- The indicator *Pesticides in Farmland Streams and Ground Water* (Chapter 2, Purer Water), captures the extent to which chemical conditions in streams may exceed the tolerance limits for aquatic communities. All streams monitored by the National Water Quality Assessment (NAWQA) program in farmland areas had at least one pesticide at detectable levels throughout the year (The Heinz Center, 2002). About 75 percent of these streams had an average of five or more pesticides at detectable levels, and more than 80 percent of the streams had at least one pesticide whose concentration exceeded the applicable aquatic life guideline. About 60 percent of ground water wells sampled in agricultural areas had at least one pesticide at detectable levels. A relatively small number of these chemicals—specifically the herbicides atrazine (and its breakdown product desethylatrazine), metalachlor, cyanazine, and alachlor—accounted for most detections.
- The *Potential Pesticide Runoff from Farm Fields* indicator (Chapter 3, Better Protected Land) identifies the potential for movement of agricultural pesticides by surface water runoff in watersheds nationwide, based on factors known to be important determinants of pesticide loss. These factors include: 1) soil characteristics, 2) historical pesticide use, 3) chemical properties of the pesticides used, 4) annual rainfall and its relationship to runoff, and 5) major field crops grown. The indicator uses 1992 as a baseline. Watersheds with high scores (i.e., the 4th quartile of runoff estimates) have a greater risk of pesticide contamination of surface water than do those with low scores (i.e., the 1st quartile of runoff estimates). The highest potential for pesticide runoff is projected for the central U.S., primarily in the upper and lower Mississippi River valley and the Ohio River valley. These areas are part of the "breadbasket" of the U.S., where pesticide application is highest. Many of the western watersheds have not been assessed.
- The hydrologic attribute indicator *Sediment Runoff Potential from Croplands and Pasturelands* (Chapter 3, Better Protected Land), captures the loss of valuable soil from the farmland, sediment impacts to the physical habitat of farmland streams, and transport of many pollutants to downstream lakes, reservoirs, and estuaries. This indicator combines land cover, weather patterns, and soils information in a process model that incorporates hydrologic cycling, weather, sedimentation, crop growth, and agricultural management to estimate the amount of sediment that could potentially be delivered to rivers and streams in each watershed. The highest potential for sediment runoff is concentrated in the central U.S., predominately associated with the upper Mississippi River valley and the Ohio River valley. Most of the western U.S. region is characterized by low runoff potential.

The other three indicators in Exhibit 5-16, described on the following pages, appear for the first time in this chapter.

Indicator Pesticide leaching potential - Category 2

Retention of pesticides in their target areas maximizes pesticide efficiency and minimizes off-site contamination (Hellkamp, et al., 2000). Pesticide leaching not only can contaminate surface and ground water, but also can have both chronic and acute toxic effects on non-target organisms, such as fish, birds, and other wildlife. This leaching potential is affected by soil properties, rainfall and runoff, pesticide chemistry, and other factors. The indicator was used as part of the NASS survey approach, so it has the potential for national application.

What the Data Show

During the 1994-1995 period, there were about 13.5 million acres of cropland in the MId-Atlantic region (Hellkamp et al, 2000). Although a large proportion of these 13.5 million acres had soils with properties conducive to pesticide leaching, the authors estimate that 50 percent (6.75 million acres) of the cropland received no pesticide application. Also, pesticides with moderately high to high leaching potentials were seldom applied to croplands with highly to very highly leachable soils. Consequently, only about 1 million acres (less than 10 percent of the total cropland acreage) was at moderately high to high risk for loss of pesticides from the on-farm target area (Hellkamp, et al., 2000).

Indicator Gaps and Limitations

The limitations of this indicator include the following:

- The pesticide leaching potential indicator has only been applied in the mid-Atlantic region and has not been tested or applied in other regions. It has the potential to be applied in other areas, but it will have to be adjusted for regional differences.
- Data collection occurred only during 1994 and 1995.

Data Source

The data source for this indicator was the Mid-Atlantic Integrated Assessment Program, U.S. Environmental Protection Agency (1994-1995). (See Appendix B, page B-41, for more information.)

Indicator Soil quality index - Category 2

A Soil Quality Index (SQI) was developed and measured for agroecosystems in the mid-Atlantic region in 1994 and 1995 (Hess, et al., 2000; Hellkamp, et al., 2000). The SQI includes indicators of soil attributes, including physical (i.e., clay content, cation exchange capacity, base saturation), chemical (i.e., pH, sodium adsorption ratio, total nitrogen, total carbon, organic carbon/clay), and biological (i.e., microbial biomass). The SQI score is an average of eight numerical ratings (McQuaid and Olson, 1998) (Hellkamp, et al., 2000). The high soil quality range begins at SQI scores of 2.4, while the range of low SQI scores is from 0.0 to 1.6. While the SQI is an indicator of the capacity of the soil to support plant growth and is related primarily to agricultural productivity, it can also provide information on the capacity of the site to support non-agronomic plants.

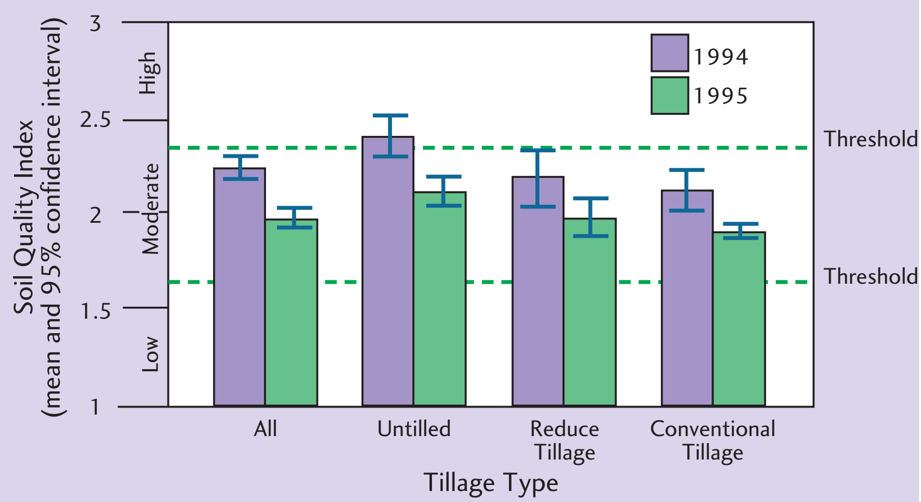
This indicator was used as part of the NASS survey approach, so it has the potential for national application.

What the Data Show

SQI scores were obtained for the five-state mid-Atlantic region in 1994 and 1995 (Hellkamp, et al., 2000) (Exhibit 5-17). In 1994, the mean SQI score was 2.23 (CI[9] = 2.17 to 2.29); in 1995, the mean SQI was 1.98 (CI = 1.73 to 2.23). The difference in SQI scores between 1994 and 1995 was due to different index calculation procedures and sampling variability. SQI scores were lower in tilled soils compared with untilled soils, such as hay fields, in both 1994 and 1995. Untilled sites had higher microbial biomass values than conventional or reduced tillage sites in both years

Evaluation of the individual factors related to the moderate SQI scores indicated that cation exchange capacity (1994), carbon (total 1994, organic 1995), and microbial biomass (1995) had the lowest values (Hellkamp, et al., 2000).

Exhibit 5-17: Soil quality index for different tillage systems in the mid-Atlantic states, 1994 and 1995



Dashed lines represent thresholds between low, moderate, and high ranges in soil quality for supporting plant growth.

Coverage: Mid-Atlantic states.

Source: Hellkamp et al. *Assessment of the Condition of Agricultural Lands in Six Mid-Atlantic States. 2000.*

Increasing the carbon content of soils might increase their capacity to support plant growth. Retaining or adding crop residues to the soils could increase both the carbon content and substrate for microbial activity. Crop residues can also reduce soil erosion and associated transport of nutrients and pesticides off the field. Nutrients and pesticides contribute to negative effects on aquatic receiving systems.

Indicator Gaps and Limitations

Data are available only for the mid-Atlantic region for 2 years. The indicator has the potential to be applied in other areas, but it will have to be adjusted for regional differences.

Data Source

The data source for this indicator was the Mid-Atlantic Integrated Assessment Program, U.S. Environmental Protection Agency (1994-1995). (See Appendix B, page B-41 for more information.)

[9]The confidence interval (CI) of the mean is a range of values (interval) with a known probability (confidence, in this case 95 percent) of containing the true population mean. The 1994 measured SQI scores are only a sample of the entire population of SQI scores for the region. While the mean of the measured SQI scores was 2.23, there is a 95 percent probability that the mean for the entire population would be between 2.17 and 2.29.

Indicator | Soil erosion - Category 2

Sediment resulting from soil erosion and transport is the greatest pollutant in aquatic ecosystems, both by mass and volume (EPA, OW, August 2002). Soil particles also can transport sorbed nutrients and pesticides and carry these into aquatic systems where these constituents contribute to water quality problems. Agricultural soil erosion decreases soil quality and can reduce soil fertility, and soil movement can make normal cropping practices difficult (The Heinz Center, 2002). Soil erosion and transport can occur both by wind and by water.

Soil erosion estimates were calculated using the U.S. Geological Survey hydrologic unit codes watersheds (8-digit HUCs), National Resources Inventory soils data, the Universal Soil Loss Equation (Renard, et al., 1997), and the Wind Erosion Equation (Bondy, et al., 1980; Skidmore and Woodruff, 1968). Soil parameters were obtained from the USDA Natural Resources Conservation Service database.

What the Data Show

The acreage of U.S. farmland with the greatest potential for wind erosion decreased by almost 33 percent to about 63 million acres from 1982 to 1997 (The Heinz Center, 2002) (Exhibit 5-18). This acreage represents about 15 percent of the total cropland in the U.S. The acreage with the greatest potential for water erosion also decreased by about 33 percent to 89 million acres, which represents about 22 percent of U.S. cropland (The Heinz Center, 2002). Reductions in erosion can occur through improved tilling or management practices, taking marginal land out of production, participation in the Conservation Reserve Program, or similar activities. These reductions not only can contribute to increased soil quality, but also improved water quality in adjacent and downstream aquatic ecosystems.

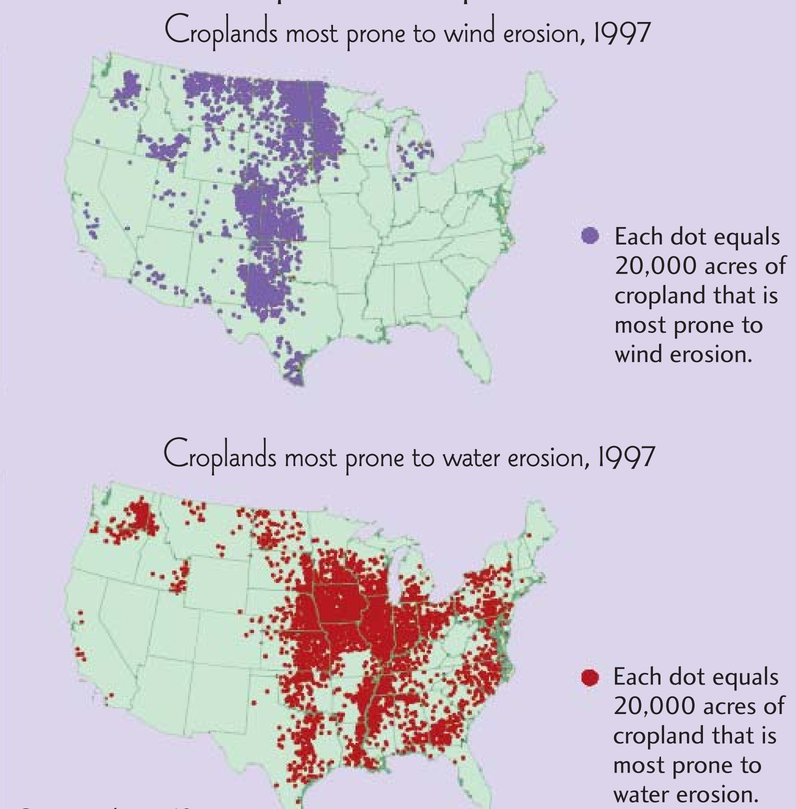
Indicator Gaps and Limitations

This indicator provides estimates for the initiation of soil movement, not sediment transport or delivery off farmlands, which would require additional measurements and calculations. The distance the soil particles are moved might be considerable or minimal and cannot be determined from soil erosion estimates.

Data Sources

The data sources for this indicator were the National Resources Inventory, U.S. Department of Agriculture (1982-1997); and the State Soil Geographic Database (STATSGO), U.S. Department of Agriculture (1982-1997). (See Appendix B, page B-42, for more information.)

Exhibit 5-18: Croplands most prone to erosion, 1997



Coverage: lower 48 states.

Note: data cover cropland and Conservation Reserve Program lands, but not pasture.

Source: The Heinz Center. *The State of the Nation's Ecosystems.* 2002. Data from the USDA, Natural Resources Conservation Service.

Summary: The Ecological Condition of Farmlands

Farmlands represent a significant portion of the landscape, but their ecological condition nationally, or even for most regions, is unknown. In a limited number of watersheds in which agricultural lands are the predominant land use, data indicate that concentrations of nitrate, phosphorus, and many contaminants are above levels of concern, but these data are not available for a representative sample of streams that could serve as a baseline for water quality management decisions for the entire U.S. No data for national indicators are available for three of the six essential ecological attributes, and many of the indicators for the other EEAs relate primarily to crop or livestock production. Habitat alteration and constituent loading from farmlands represent some of the major stressors on other ecosystems (see Chapter 2, Purer Water, and Chapter 3, Better Protected Land, for discussion of specific stressors.)

Landscape condition

While there is no single, definitive, accurate estimate of the extent of cropland, it has been estimated to have decreased by 10.4 percent between 1982 and 1997, from about 421 million acres to nearly 377 million acres. Of this 44-million acre decrease, 32.7 million acres are now enrolled in the CRP, leaving an 11.3 million acre loss as a result of conversion of croplands to other land uses. The Heinz report assesses total cropland (including pasture and hayland) as covering between 430 and 500 million acres in 1997, or about a quarter of the total land area in the U.S. (excluding Alaska). In many areas of the U.S., other land cover types within croplands are almost as prevalent as croplands themselves and can provide habitat for non-agronomic species. For example, croplands comprise only half of the larger farmland ecosystems in the East and Southeast and about three-quarters of the farmland ecosystems in the Midwest. This situation suggests that much of the farmland in the country supports more biodiversity and associated ecological processes than if it were more completely monoculture. Indicators for fragmentation of farmland landscapes by development and the shape of "natural" patches in farmland landscapes would be helpful additional indicators of landscape condition (The Heinz Center, 2002).

Chemical and physical characteristics

The physical and chemical characteristics of farmlands could provide information to measure national progress in controlling and managing non-point source pollutant transport to receiving waters under EPA's clean water Government Performance and Results Act (GPRA) goal. Unfortunately, many of the indicators for physical and chemical characteristics are estimated based on land use, rather than on measurements of water quality. The National Water Quality Assessment (NAWQA) program provides consistent and comparable information on nutrient and pesticide concentrations in streams in agricultural areas. The data show that nitrate and phosphorus concentrations in farmland streams are generally higher than in urban and suburban streams, and that more than 80 percent of the streams sampled had at least one pesticide whose concentration exceeded guidelines for protection of aquatic life. The sites sampled do not represent a probability sample and are too few to ensure that these data are representative of farmlands nationwide. Additional stream monitoring networks are required to assess the physical and chemical characteristics of streams in agricultural areas and the effectiveness of agricultural management practices for protecting or improving stream quality. A *pesticide leaching potential* indicator and a *soil quality index* indicate that only 10 percent of the soils in the mid-Atlantic region were highly leachable with respect to pesticides, and that soil quality was in the "moderate" range, but the indicator has not been widely applied elsewhere.

Hydrology and geomorphology

Sediment Runoff results in loss of valuable soil from the farmland, sediment impacts to the physical habitat of farmland streams, and transport of many pollutants to downstream lakes, reservoirs, and estuaries. The highest potential for sediment runoff is concentrated in upper Mississippi River valley and the Ohio River valley. Most of the western U.S. region is characterized by low runoff potential. Between 1982 and 1997, the acreage with the greatest potential for water erosion decreased by about 33 percent to 89 million acres, which represents about 22 percent of U.S. cropland. Wind can also erode soil. The acreage of U.S. farmland with the greatest potential for wind erosion decreased by almost 33 percent to about 63 million acres from 1982 to 1997, about 15 percent of the total cropland in the U.S. There were no indicators of hydrology available for either surface or ground water associated with agricultural ecosystems. Modification or elimination of wetlands and riparian areas contributes to hydrologic alteration of farmlands, as does agricultural irrigation, primarily in the western states. This consumption affects not only surface water through irrigation return flows, but also ground water through depletion of aquifers. Both water quantity and quality can be affected in farmlands. No national, representative monitoring programs exist for either the quantity or quality of water in farmlands.

No Category 1 or 2 indicators were available for this report for *biotic condition, ecological processes,* or *natural disturbance regimes.* The Heinz Center (2002) suggested that several indicators could be promising: soil biological condition, status of animal species in farmland areas, native vegetation in areas dominated by cropland, and stream habitat quality. An indicator of ant diversity and wildlife habitat also was developed and tested in the mid-Atlantic region by the Mid-Atlantic Integrated Assessment Program (MAIA). Data are insufficient, however, to report on agroecosystems nationally for any of these indicators (Hellkamp, et al., 2000; The Heinz Center, 2002). A particular problem in farmlands is establishing appropriate reference conditions for biological structure and ecosystem function measures (The Heinz Center, 2002). Agricultural systems are highly managed ecosystems, so no natural reference exists. It would be unrealistic to expect fish and invertebrate communities in farmlands to be comparable to relatively undisturbed forest or grassland ecosystems.

5.4 What Is the Ecological Condition of Grasslands and Shrublands?

Grasslands and shrublands include lands in which the dominant vegetation is grasses or other non-woody vegetation, or where shrubs and scattered trees are typical (The Heinz Center, 2002). This ecosystem type includes chaparral, deserts, mountain shrublands, range lands, Florida grasslands, and non-cultivated pastures. Grasslands and shrublands also can be used for grazing, so some land use summaries may include them in estimates of farmlands. Grasslands and shrublands include lands revegetated naturally or artificially to provide a non-crop plant cover that is managed like native vegetation. The vast majority of grasslands and shrublands occur in the western U.S. Collectively, these ecosystems constitute over one-third of the area in the conterminous U.S.

Environmental issues associated with grassland and shrubland ecosystems include introduction of non-native and invasive species, desertification, ground water depletion, and overgrazing. Several federal agencies (e.g., Bureau of Land Management, Forest Service, National Park Service) have responsibility for the majority of publicly owned grasslands and shrublands.

Ecological indicators used in this report for grassland and shrubland ecosystems are listed in Exhibit 5-19. The Heinz report serves as the primary source of information for this ecological resource (The Heinz Center, 2002). The following indicators presented in previous chapters relate to the ecological condition of grasslands and shrublands:

- The *Extent of Grasslands and Shrublands* indicator (Chapter 3, Better Protected Land) reveals that grasslands and shrublands occupy about 861 million acres or just over one-third of the land area in the conterminous U.S. states. Alaska contains about 205 million acres of grasslands and shrublands.
- *Number/Duration of Dry Stream Flow Periods in Grasslands and Shrublands* (Chapter 2, Purer Water) is an important indicator of the hydrology of grasslands and shrublands. This indicator shows that the percentage of no-flow periods has decreased in all grassland and shrubland regions of the West (The Heinz Center, 2002). The percentage of no-flow periods was similar in 1950 and 1960 and then decreased in the 1970s, 1980s, and 1990s. The 1980s was a relatively wet period and experienced some of the smallest percentages of no-flow periods over the 50-year period on record. The duration of zero-flow periods also decreased during the period from the 1970s through the 1990s, compared to the 1950s and 1960s (The Heinz Center, 2002).

The two biotic structure indicators in Exhibit 5-19, described on the following pages, appear for the first time in this chapter: *At-Risk Native Species* and *Population Trends of Invasive and Native, Non-invasive Birds.*

Exhibit 5-19: Grasslands and shrublands indicators

Essential Ecological Attribute	Indicators	Category		Source
Landscape Condition		1	2	
Extent of Ecological System/Habitat Types	Extent of grasslands and shrublands	■		DOI
Landscape Composition				
Landscape Structure/Pattern				
Biotic Condition				
Ecosystems and Communities	At-risk native grassland and shrubland species		■	NatureServe
	Population trends in invasive and native non-invasive bird species	■		DOI
Species and Populations				
Organism Condition				
Ecological Processes				
Energy Flow				
Material Flow				
Chemical and Physical Characteristics				
Nutrient Concentrations				
Other Chemical Parameters				
Trace Organics and Inorganics				
Physical Parameters				
Hydrology and Geomorphology				
Surface and Ground Water Flows	Number/duration of dry stream flow periods in grasslands/shrublands	■		DOI
Dynamic Structural Conditions				
Sediment and Material Transport				
Natural Disturbance Regimes				
Frequency				
Extent				
Duration				

Indicator

At-risk native grassland and shrubland species - Category 2

Native species contribute substantially to the goods and services provided by grasslands and shrublands. These species have evolved in and adapted to the reange of environmental conditions that has occurred in grassland and shrubland ecosystems over thousands of years. While species extinction is a natural geologic phenomenon, the extinction of species has increased over the past 100 years (Vitousek, et al., 1997), and many ecologists believe that ecosystem function and resilience is related to biodiversity (Naeem, et al., 1999), so that preserving biodiversity is critical for sustainable ecosystems. Whether or not this is always the case[10] many people believe that more species is preferable to fewer species.

What the Data Show

About 3.5 percent of native grassland and shrubland animal species are critically imperiled, 6 percent are imperiled, and 0.5 percent are or might be extinct (The Heinz Center, 2002) (Exhibit 5-20). When vulnerable species (7 percent) are counted, about 17 percent of grassland and shrubland animal species are considered "at risk."

Indicator Gaps and Limitations

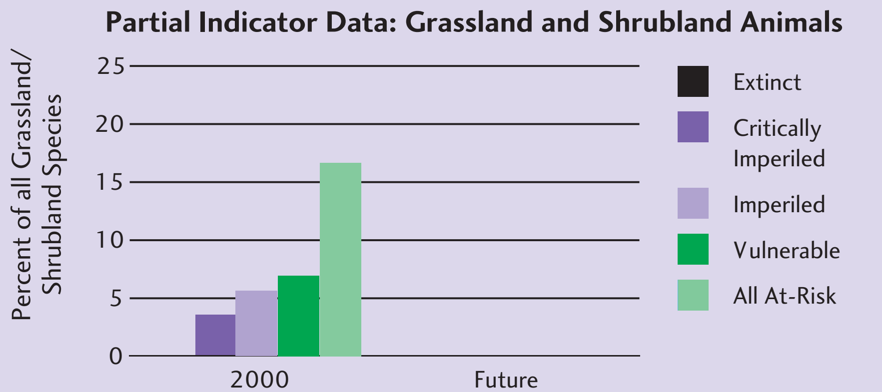
The data for this indicator are not from a site-based monitoring program, but rather from a census approach that focuses on the location and distribution of at-risk species. Determining whether species are naturally rare or have been depleted is currently not possible. It is not clear that trends can be quantified with any precision.

Data Source

The data source for this indicator was *The State of the Nation's Ecosystems,* The Heinz Center, 2002, using data from NatureServe Explorer database. (See Appendix B, page B-42, for more information.)

Exhibit 5-20: At-risk native grassland and shrubland species, by risk category, 2000

Data Not Adequate for National Reporting on Grassland and Shrubland Plants



Coverage: all 50 states.

Source: The Heinz Center. *The State of the Nation's Ecosystems.* 2002. Data from NatureServe and its Natural Heritage member programs.

[10] An ongoing debate exists within the scientific community on the importance of species diversity in sustaining ecosystem functoin (Tilman and Downing, 1994; Grime, 1997; Hodgson, et al., 1998; Wardle, et al., 2000)

Indicator Population trends of invasive and native, non-invasive birds - Category 1

Bird species are mobile and can respond quickly to environmental change (The Heinz Center, 2002). The Heinz report uses an indicator of population trends in invasive and non-invasive birds to determine if invasive bird species are increasing more than other bird populations (The Heinz Center, 2002). Invasive species are defined as non-native species (species that are not native to North America or that are now found outside their historic range) that spread aggressively. Some invasive bird species increase when the landscape becomes more fragmented or stress on the ecological system increases. The invasive species considered for grassland and shrublands are believed to be indicative of agricultural conversion, landscape fragmentation due to suburban and rural development, and the spread of exotic vegetation (The Heinz Center, 2002). Native, non-invasive species are considered to reflect relatively intact, high-quality native grasslands and shrublands (The Heinz Center, 2002).

What the Data Show

Since the late 1960s, invasive and non-invasive bird species increased in similar proportions until the period 1996 to 2000, when invasive species increased significantly (The Heinz Center, 2002) (Exhibit 5-21). This increase might represent a short-term fluctuation in bird populations, or it could be a sign of changing ecosystem condition. Continued monitoring of bird populations and indicators in other essential ecological attributes is required to evaluate these changes.

Indicator Gaps and Limitations

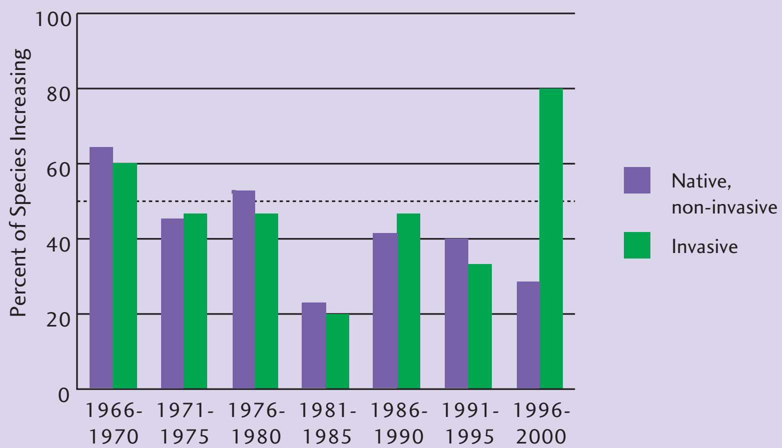
The limitations of this indicator include the following:

- The calculation method could mask increases or decreases in particular species. The two groups of birds contain species that differ in their habitats, relative abundance, and range, and bird populations normally fluctuate from year to year. If half the species in one of the groups were to increase and the other half to decrease over a given period, no consistent change would appear for that group (The Heinz Center, 2002).
- The recent period of change is too short to provide an indication of a possible increasing trend in invasive bird species.

Data Source

The data source for this indicator was the Breeding Bird Survey, U.S. Geological Service (1966-2000). (See Appendix B, page B-42, for more information.)

Exhibit 5-21: Population trends of invasive and native, non-invasive birds, 1966-2000



Coverage: selected grassland and shrubland areas.

Source: The Heinz Center. *The State of the Nation's Ecosystems.* 2002. Data from the U.S. Geological Survey, Breeding Bird Survey; analysis by W. Mark Roberts.

Summary: The Ecological Condition of Grasslands and Shrublands

Grassland and shrubland ecosystems are at risk from the introduction of non-native and invasive species, desertification, ground water depletion, and overgrazing. Few ecological indicators are currently being measured at a national or regional scale, and this situation is unlikely to change in the near future, so the overall ecological condition of the nation's grasslands and shrublands is and will remain effectively unknown.

Landscape condition

The extent of grasslands and shrublands can be estimated from National Land Cover Database (NLCD) information. Grasslands and shrublands occupy about 861 million acres or just over one-third of the land area in the conterminous U.S. Alaska contains about 205 million acres of grasslands and shrublands. This is a diverse group of ecosystems, however, ranging from Florida grasslands to the Mohave desert, and land use information is not readily available for all of them.

Biotic condition

At-risk native species and population trends in invasive and non-invasive birds are two indicators that can provide information on the status of, and change in, biotic condition. About 3.5 percent of native grassland and shrubland animal species are critically imperiled, 6 percent are imperiled, and 0.5 percent are or might be extinct. When vulnerable species (7 percent) are counted, about 17 percent of grassland and shrubland animal species are considered "at risk." However, there is no context in which to interpret the at-risk native species data. The proportion of species that would naturally be rare is unknown. Invasive species are believed to be indicative of agricultural conversion, landscape fragmentation due to suburban and rural development, and the spread of exotic vegetation, whereas native, non-invasive species are considered to reflect relatively intact, high-quality native grasslands and shrublands. Until recently, invasive and non-invasive bird species have changed in similar proportions, but from 1996 to 2000, invasive species increased significantly. This might be a short-term fluctuation in bird populations, or it could be a sign of changing ecosystem condition. Information on stream biota in grasslands and shrublands are needed to be able to assess the condition of grassland and shrubland streams, especially as it may be affected by grazing.

Hydrology and geomorphology

Periods of no flow can certainly be stressful to aquatic communities of grasslands and shrublands, and may indicate harm to the vegetation during drought periods. *The Number/Duration of Dry Stream Flow Periods* indicator has decreased in all grassland and shrubland regions of the West. The percentage of no-flow periods was similar in 1950 and 1960 and then decreased in the 1970s, 1980s, and 1990s. The duration of zero-flow periods also decreased during the period from the 1970s through the 1990s, compared to the 1950s and 1960s. Currently, dry stream flow periods are not monitored nationally.

There were no Category 1 or 2 indicators available for this report f*or ecological processes, physical and chemical characteristics,* or *natural disturbance regimes* for grasslands and shrublands.

5.5 What Is the Ecological Condition of Urban and Suburban Areas?

Urban and suburban ecosystems are areas where the majority of the land is devoted to or dominated by buildings, houses, roads, concrete, grassy lawns, or other elements of human use and construction (The Heinz Center, 2002). Urban ecosystems are highly built-up and paved over, resulting in more rapid changes in temperature, runoff, and other variables than in more natural ecosystems. Plant and animal life is heavily influenced by species introduced in horticulture and as pets, and native plant species might be more or less completely removed from large areas and replaced by lawns, gardens, and ornamentals (WRI, 2000). These areas generally show high levels of many air and water pollutants because of the concentration of pollutant sources in small areas. Nonetheless, substantial biodiversity

Exhibit 5-22: Urban and suburban indicators

Essential Ecological Attribute	Indicators	Category		Source
Landscape Condition		1	2	
Extent of Ecological System/Habitat Types	Extent of urban and suburban lands	■		USDA
Landscape Composition	Patches of forest, grassland, shrubland, and wetland in urban/suburban areas		■	DOI
Landscape Structure/Pattern				
Biotic Condition				
Ecosystems and Communities				
Species and Populations				
Organism Condition				
Ecological Processes				
Energy Flow				
Material Flow				
Chemical and Physical Characteristics				
Nutrient Concentrations	Nitrate in farmland, forested and urban streams and ground water		■	DOI
	Phosphorus in farmland, forested and urban streams		■	DOI
Other Chemical Parameters				
Trace Organics and Inorganics	Chemical contamination in urban streams and ground water		■	DOI
	Ambient concentrations of ozone, 8-hour and 1-hour	■		EPA
Physical Parameters				
Hydrology and Geomorphology				
Surface and Ground Water Flows				
Dynamic Structural Conditions				
Sediment and Material Transport				
Natural Disturbance Regimes				
Frequency				
Extent				
Duration				

can remain in these systems; for example, a 1993 survey identified 115 bird species in Washington, DC (Hadidian, et al., 1997).

There is substantial interest in understanding urban and suburban ecosystems, as evidenced by two urban National Science Foundation long-term ecological research sites (Phoenix and Baltimore), a professional journal, *Urban Ecosystems* and a number of recent writings on the subject (Pickett, et al., 2001; Kinzig and Grove, 2001; Grimm, et al., 2002). Much of urban ecosystems research is aimed not at preserving natural ecosystems, but at "smart growth" and understanding how to enhance ecosystem services in a highly built environment. Despite the growing amount of research, the entire science of urban ecosystem ecology is not sufficiently developed to have a substantial number of ecological indicators. In addition, there may be a lack of understanding regarding what to expect when applying indicators typically used in less built-up land cover classes to urban and suburban ecosystems. The Heinz report lists eight indicators for urban and suburban ecosystems, only two of which have adequate data for national reporting.

Indicators for urban and suburban ecosystems used in this report are listed in Exhibit 5-22, grouped according to essential ecological attributes. Extent and chemical and physical condition data are the most widely available. There were no indicators for biotic condition, ecological processes, hydrology and geomorphology, or natural disturbance regimes for urban and suburban ecosystems suitable for national or even regional reporting (The Heinz Center, 2002).

This section summarizes data related to urban and suburban ecosystems for five indicators, most of them relating to pollutant concentrations, that appear in earlier chapters. The section then introduces one indicator that appears for the first time in this report—*Patches of Forest, Grassland, Shrubland, and Wetland in Urban/Suburban Areas*—which relates to the landscape essential ecological attribute.

The following indicators presented in previous chapters relate to the ecological condition of urban and suburban areas:

- The indicator *Extent of Urban and Suburban Lands* (Chapter 3, Better Protected Land) was assessed using the National Land Cover Database and estimating the proportion of the area in 1,000 foot pixels that fell into one of four developed land cover types: low-intensity residential; high-intensity residential; commercial-industrial-transportation; or urban and recreational grasses (The Heinz Center, 2002). In 1992, urban and suburban areas occupied about 32 million acres in the conterminous U.S. or about 1.7 percent of the total land area (The Heinz Center, 2002). As with the estimate of the extent of farmlands, urban and suburban areas are defined differently by different organizations, sometimes using different data sources, thus affecting the area estimates. For example, the Extent of Developed Lands indicator in Chapter 3, Better Protected Land is based on USDA National Resources Inventory delineation of developed lands, which is about 98 million acres in the conterminous U.S., or about 4.3 percent of the total land area of the U.S., not including Alaska (see Chapter 3, Better Protected Land).
- The indicator A*mbient Concentrations of Ozone, 8-hour and 1-hour* (Chapter 1, Cleaner Air) revealed that in 1999, about 55 percent of the urban and suburban monitoring stations had high ozone concentrations on 4 or more days, and that the percentage fluctuated between 35 percent and 60 percent during the 1990s (The Heinz Center, 2002). The number of sites with 10 days or more of high ozone fluctuated between 20 and 30 percent of the sites, with no apparent trend, but the number of sites with high ozone on 25 days or more decreased from about 10 percent to around 5 percent over the decade. Fluctuations are caused in part by changes in the weather. As noted in the section on forests, biomonitoring plots frequently reveal at least some ozone damage to tree leaves.
- The indicator *Nitrate in Farmland, Forested, and Urban Streams and Ground Water* (Chapter 2, Purer Water), shows that 40 percent of 21 streams in which the predominant land use was urban and suburban had nitrate concentrations above 1.0 ppm; 25 percent had concentrations below 0.5 ppm; and 3 percent had concentrations below 0.1 ppm (The Heinz Center, 2002). Concentrations of nitrate in these urban streams were generally lower than those of agricultural watersheds, but higher than those in forested watersheds.
- The indicator *Phosphorus in Farmland, Forested, and Urban Streams (*Chapter 2, Purer Water) showed that two-thirds of 21 urban streams sampled had phosphorus concentrations of at least 0.1 ppm, a level usually associated with excess algal growth (The Heinz Center, 2002). About 10 percent of the urban streams had concentrations of at least 0.5 ppm.
- According to the indicator *Chemical Contamination in Streams and Ground Water* (Chapter 2, Purer Water), 85 percent of 21 urban streams sampled had an average of about five detectable contaminants throughout the year (The Heinz Center, 2002). All of the streams had at least one chemical that exceeded guidelines for the protection of aquatic life. For many urban and suburban streams, the nutrient and contaminant signature is similar to the signatures from agroecosystems (The Heinz Center, 2002; Wickham, et al., 2002).

The following indicator, *Patches of Forest, Grassland, Shrubland, and Wetland in Urban/Suburban Areas,* provides data on landscape condition in urban and suburban areas.

Indicator | Patches of forest, grassland, shrubland, and wetland in urban/suburban areas - Category 2

Patches of forest, grassland, shrubland, and wetland in urban/suburban areas provide habitat for birds, amphibians, and small mammals. They also increase water infiltration and reduce temperature by evapotranspiration. Patches of urban and suburban vegetation generally reduce particulate matter, and they can increase or decrease ozone concentrations, relative to built surfaces (Nowak, et al., 2000). According to The Heinz Center (2002), the size of patches of undeveloped land in urban and suburban areas is important, with smaller patches generally considered to provide poorer quality habitat. Recent studies have indicated a significant loss of forest patch coverage in Atlanta and Baltimore in the last several decades (American Forests, 2001, 2002).

What the Data Show

Around half of the undeveloped land in urban and suburban areas occurs in patches smaller than 10 acres (Exhibit 5-23). Urban and suburban areas in the Northeast have the largest percentage of large (1,000 to 10,000 acres) patches of undeveloped land. Patches of undeveloped land larger than 10,000 acres occur only in urban and suburban areas of the West.

Indicator Gaps and Limitations

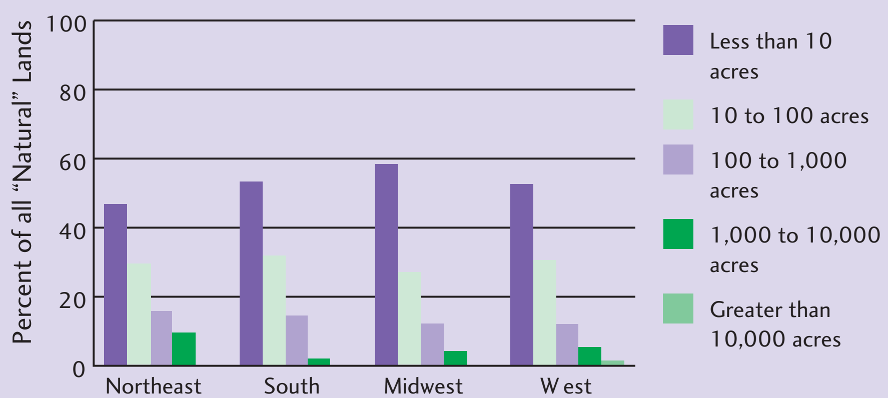
Several limitations are associated with this indicator:

- Natural patches may extend beyond the boundary of the "urban and suburban area" land use class, which would cause the size of the patches to be underestimated.
- Very small patches are difficult to distinguish if they are mixed with developed classes, which also leads to underestimates.
- Remote sensing cannot distinguish between land that has always been "non-urban" and patches, such as landfills, that have reverted to grasslands or forest.
- Patch size is not the only factor that contributes to habitat quality (The Heinz Center, 2002).

Data Source

The data source for this indicator was the National Land Cover Database, Multi-Resolution Land Characterization Consortium (1990s). (See Appendix B, page B-43, for more information.)

Exhibit 5-23: Patches of forest, grassland, shrubland, and wetland in urban and suburban areas, 1992



Coverage: lower 48 states

Source: The Heinz Center. *The State of the Nation's Ecosystems.* 2002. Data from Multi-Resolution Land Characteristics Consortium, and the USGS Earth Resources Observations Systems Data Center.

Summary: The Ecological Condition of Urban and Suburban Ecosystems

Urban and suburban systems have been the subject of increasing ecological interest, but their overall condition, nationally or even regionally, is virtually unknown.

Landscape condition

Within the technical limitations of using remote sensing data to define urban and suburban ecosystems and the landscape patches they contain, The Heinz Center (2002) has established a baseline against which to judge current trends in urbanization. In 1992, urban and suburban areas occupied about 32 million acres in the conterminous U.S. or about 1.7 percent of the total land area, but different organizations, sometimes using different data sources, produce different estimates. For example, USDA National Resources Inventory delineation of developed lands, estimates there to be about 98 million acres in the conterminous U.S., or about 4.3 percent of the total land area of the U.S., not including Alaska (see Chapter 3, Better Protected Land). However, there is currently no firm plan in place to collect the remote sensing data in the future to allow trends to be calculated. Although the land use indicators identified provide some useful information on extent, they do not address the actual condition of those lands. Given the concentration of the human population in developed areas of the country, a better understanding of the interaction among humans and their developed environment could help improve human health and the effects of developed lands on ecological condition.

Chemical and physical characteristics

Chemical data from the NAWQA program used to develop the stream quality indicator in this report and the Heinz report (2002) include only 21 urban streams across the entire U.S. Nitrate and phosphorus concentrations in these streams were intermediate between farmlands and forest streams, but all of them had at least one chemical that exceeded guidelines for the protection of aquatic life. Given the numerous factors that can affect these systems, 21 streams are not likely to be an adequate baseline against which to track the progress of environmental protection activities, including stormwater management, controls on non-point source pollution from lawns, golf courses, and septic systems, with any statistical certainty. An indicator of the extent of impervious surfaces might be useful for inferring non-point source pollution impacts.

There were no Category 1 or 2 indicators available for this for *biotic condition, ecological processes,* or *natural disturbance regimes.* The Heinz Center (2002) identified several indicators that could be promising but for which there are not even regional data:

- An indicator that would report on the percentage of urban and suburban areas in which <25 percent, 25 to 50 percent, 50 to 75 percent, and >75 percent of the original species had been lost or displaced.
- An indicator that would report on the number of nuisance species in urban and suburban areas (e.g., white-tailed deer, kudzu).
- Fish Index of Biotic Integrity (IBI) and Macroinvertebrate Biotic Integrity Index (MBII) indicators in urban/suburban streams.
- An indicator that would report on the coverage of stream bank vegetation.

The lack of national biotic indicators for urban fresh water systems makes it particularly difficult to measure national progress in maintaining balanced communities in urban streams.

A particular problem in urban and suburban systems is establishing appropriate reference conditions for biological structure and ecosystem function measures (The Heinz Center, 2002). For example, expecting fish and invertebrate communities in urban streams to be typical of relatively undisturbed forest or grassland ecosystems would be unrealistic. Data are insufficient on both the current status of species and the original species present to calculate the number of native species lost. As another example, an indicator tracking national trends in urban stream buffers would be particularly helpful to states tracking the effectiveness of watershed management programs. However, a decision would be needed on a threshold for buffer strips of adequate width to protect stream channels, and further development of satellite measurements would be needed before such an indicator could be used for national reporting.

A potentially useful hydrology/geomorphology indicator would be the percentage of impervious area (The Heinz Center 2002). Impervious areas generally increase runoff from rain events, leading to modified stream channels, increased stream temperatures, decreased infiltration, and pollutants carried into ecosystems (e.g., Booth and Jackson, 1997). According to The Heinz Center, however, although some local governments collect data on impervious surfaces, it is difficult to measure (Arnold and Gibbons, 1996), and there are insufficient data on this indicator for national reporting. Tracking impervious surface changes may be important for measuring progress in reducing the impact of stormwater runoff on the quality of receiving streams.

Another potentially useful indicator is the urban heat island (The Heinz Center 2002). Urban heat islands raise the ambient temperature surrounding both terrestrial and aquatic ecosystems. Because chemical and biological reaction rates are temperature dependent, increased heating and temperatures can increase the stress on all biological species, both directly and indirectly. Dissolved oxygen saturation is lower in warmer water, so aquatic organisms, with higher metabolic rates and the need for greater oxygen supplies, have less oxygen available in the water because of lower oxygen saturation in warm water. The heat island effect can also have important impacts on air quality in urban and downwind areas (Nowak, et al., 2000). Again, the data may be available to calculate this indicator, but it has not been developed nationally.

5.6 What Is the Ecological Condition of Fresh Waters?

Fresh waters include wetlands, lakes and reservoirs, and streams and rivers. Wetlands are areas where saturation with water is the dominant factor determining the types of plant and animal communities. Wetlands vary widely because of differences in soils, topography, climate, hydrology, water chemistry, vegetation, and other factors. Two general categories of wetlands are recognized: coastal (tidal) wetlands and inland (non-tidal) wetlands. Wetlands have been threatened by outright loss and conversion from one type to another, but programs designed to restore or enhance wetlands, such as the Wetlands Reserve Program, as well as state, local, and private initiatives on agricultural lands, have resulted in reduced losses (see Chapter 2, Purer Water).

The U.S. contains more than 3.7 million miles of streams and rivers. About 60 percent of all these stream miles are found in small, head-

Exhibit 5-24: Fresh water indicators

SAB Framework	Indicators	Category		Source
Landscape Condition		1	2	
Extent of Ecological System/Habitat Types	Wetland extent and change	■		DOI
	Extent of ponds, lakes, and reservoirs	■		DOI
Landscape Composition	Altered fresh water ecosystems		■	DOI
Landscape Structure/Pattern				
Biotic Condition				
Ecosystems and Communities	Non-native fresh water fish species		■	DOI
	Animal deaths and deformities		■	DOI
	At-risk fresh water plant communities		■	NatureServe
	Fish Index of Biotic Integrity in streams		■	EPA
	Macroinvertebrate Biotic Integrity Index for streams		■	EPA
Species and Populations	At-risk native fresh water species		■	NatureServe
Organism Condition	Contaminants in fresh water fish		■	DOI
Ecological Processes				
Energy Flow				
Material Flow				
Chemical and Physical Characteristics				
Nutrient Concentrations	Phosphorus in large rivers		■	DOI
	Lake Trophic State Index		■	EPA
Trace Organic and Inorganic Chemicals	Chemical contamination in streams		■	DOI
Other Chemical Parameters	Acid sensitivity in lakes and streams		■	EPA
Physical Parameters				
Hydrology and Geomorphology				
Surface and Ground Water Flows	Changing stream flows	■		DOI
Dynamic Structural Conditions				
Sediment and Material Transport	Sedimentation index		■	EPA
Natural Disturbance Regimes				
Frequency				
Extent				
Duration				

water streams. The U.S. also contains more than 60 million acres of lakes, ponds, and reservoirs. Natural lakes are generally located in previously glaciated areas of the Northeast and Midwest, in mountainous areas, and as sinkholes or seepage lakes in Florida. Oxbow lakes are associated with former meanders of river systems. Reservoirs predominate in the West and in the unglaciated areas of the South and Southeast. Ponds, both manmade and natural, are found throughout the U.S. (see Chapter 2).

Many of the problems facing fresh water systems are similar: low dissolved oxygen, eutrophication, acidification, toxic materials in air deposition (e.g., mercury), point and non-point discharges and sediments, siltation, hydrologic modification, temperature modification, effects of Ultraviolet-B (UV-B) radiation, invasive species, overfishing, and more recently, endocrine-disrupting chemicals (e.g., Naiman and Turner, 2000). According to the most recent 305(b) report required bi-annually under the Clean Water Act, approximately one-half of the lakes and slightly more than one-half of the streams assessed by the states do not meet the designated use assigned to them by the state in which they are located (EPA, OW, August 2002).[11]

There have been several systematic efforts over the past three decades to report on the condition of lakes and stream ecosystems with respect to some of these issues:

- The U.S. Fish and Wildlife Service (USFWS) conducted the National Fisheries Survey to determine the condition of fish communities in the nation's streams (Judy, et al., 1984). The survey used a probability design, and fish community condition was based on expert opinion, rather than collection of field data.
- The National Surface Water Survey (NSWS) used a probability design to assess the acidity of lakes and streams in all areas of the U.S. sensitive to acid deposition (NAPAP, 1991; Baker, et al., 1991; Kaufmann, et al., 1991).
- The Temporally Integrated Monitoring of Ecosystems (TIME) program has continued monitoring a representative sample of acid sensitive lakes and streams, in the Northeast and Appalachians (Stoddard, et al., 1999).
- The National Water Quality Assessment (NAWQA) network samples surface fresh water ecosystems in 50 watersheds, and makes measurements of chemistry and biota (<http://water.usgs.gov/nawqa/>).
- The Environmental Monitoring and Assessment Program (EMAP) conducted a pilot survey of streams in the mid-Atlantic states, measuring chemistry and biota (Herlihy, et al., 2000). Surveys are ongoing in the western states and have just begun in large river systems of the mid-continent.

This substantial experience has contributed progress in monitoring ecological condition in lakes and streams, but there are still few Category 1 indicators.

Exhibit 5-24 shows the fresh water indicators used in this report, grouped according to the essential ecological attributes. Nine of these indicators are discussed in the previous chapters. This section briefly summarizes those indicators, and then introduces seven new ones. There are no indicators available for national or regional reporting for ecological processes or natural disturbance regimes (The Heinz Center, 2002). Indicators presented in previous chapters include:

- The indicator *Wetland Extent and Change* (Chapter 2, Purer Water) shows that since European settlement of the conterminous U.S., more than half of the original 220 million acres of wetlands have been drained and filled. Wetland types include fresh water forested, shrub, and emergent wetlands, plus open water ponds. By 1997, total wetland acreage was estimated to be 105.5 million acres (Dahl, 2000). Of that total, nearly 95 percent or 100.2 million acres were fresh water, and about 5 percent or 5.3 million acres were intertidal marine and estuarine. Rates of annual wetland losses have been dropping from almost 500,000 acres a year three decades ago to less than 100,000 acres averaged annually since 1986. The loss rate between 1986 and 1997 was estimated to be 58,500 acres per year, an 80 percent reduction in the rate of loss from the previous decade.

  A related ecological impact has been the conversion of one wetland type to another, such as clearing trees from a forested wetland or excavating a shallow marsh to create an open water pond. Open water ponds, which have more than doubled in area since the 1950s, are not the ecological equivalent of fresh water emergent marshes. Such conversions change habitat types and community structure in watersheds and impact the animal communities that depend on them.

  Urban development accounted for an estimated 30 percent of all wetland losses. Estimates for the other loss categories included 26 percent to agriculture, 23 percent to silviculture, and 21 percent to rural development. An estimated 98 percent of all wetlands converted to other uses were fresh water wetlands (Dahl, 2000).

  Forested and emergent wetlands make up over 75 percent of all fresh water wetlands. Since the 1950s, fresh water emergent wetlands have declined by nearly 24 percent, more than any other fresh water wetland type. Fresh water forested wetlands have sustained the greatest overall losses—10.4 million acres since the 1950s.
- Physically altering a fresh water body to increase some other benefit (e.g., flood control, navigation, reduced erosion, or increased area for farming or development) also may change fish

[11] While these statistics are reported biannually, because the states use different measures and monitoring designs, the results do not provide a comparable and consistent picture of the condition of lakes and streams nationally (USGAO, 2000). See Section 2.2.1 for a discussion of recent progress on this issue.

and wildlife habitat, disrupt patterns and timing of water flows, act as barriers to animal movement, or reduce or increase natural filtering of sediment and pollutants. The indicator *Altered Fresh Water Ecosystems* (Chapter 2, Purer Water), reveals that 23 percent of the banks of both rivers and streams (riparian areas) and lakes and reservoirs have either croplands or urban development in the narrow area immediately adjacent to the stream. Data on the degree to which streams and rivers are channelized, leveed, or impounded are not available. According to Dahl (2000), 78,100 acres (31,600 hectares) of forested wetlands were converted to fresh water ponds. Conversions of forested wetlands to deep water lakes resulted from human activities by either creating new impoundments or raising the water levels on existing impoundments, thus killing the trees.

- The indicator *Contaminants in Fresh Water Fish* (Chapter 2, Purer Water) reported on contaminants in fish tissue for the entire U.S., including polychlorinated biphenyls (PCBs), organochlorine pesticides, and trace elements (The Heinz Center, 2002). The presence of contaminants can be harmful to the organisms themselves, or can affect reproduction, and they can make fish unsuitable for consumption. Half of the fish tested had at least five contaminants at detectable levels, and approximately the same number had one or more contaminants at levels that exceeded the aquatic life guidelines.

  For Mid-Atlantic Highland streams with sufficient fish tissue for analysis (44 percent of stream miles did not have sufficient quantities of fish tissue), about 4 percent of the stream miles had fish tissue mercury concentrations that exceeded wildlife criteria (EPA, ORD, Region 3, August 2000).

- For the the indicator *Phosphorus in Large Rivers* (Chapter 2, Purer Water), The Heinz Center (2002) reports that half of the rivers tested had total phosphorus concentrations of 100 ppb or higher. This concentration (100 ppb) is EPA's recommended goal for preventing excess algal growth in streams that do not flow directly into lakes. None of the rivers had concentrations below 20 ppb, a level generally held to be free of negative effects (EPA, OW, November 1986). Data were insufficient to report on lakes and reservoirs nationally.

- The indicator *Lake Trophic State Index* (Chapter 2, Purer Water) assessed the nutrient or total phosphorus (TP) concentrations in northeast lakes (Peterson, et al., 1998). Once phosphorus enters lakes, it frequently serves as the nutrient that limits the growth of nuisance blooms of phytoplankton (algae). National data on lake trophic condition are not available. However, regional patterns of lake trophic condition were assessed for a target population of 11,076 Northeast lakes sampled as part of the EPA EMAP during summers from 1991 to 1994 using the Lake Trophic State Index. It was found that 37.9 percent (±8.4 percent)[12] of the lakes were oligotrophic (TP<10 ppb), 40.1 percent (±. 9.7 percent) were mesotrophic (10<TP<30 ppb), 12.6 percent (±.7.9 percent) were eutrophic (30<TP<60 ppb), and 9.3 percent (±.6.3 percent) were hypertrophic (TP>60 ppb) (Peterson, et al., 1998).

- The indicator *Chemical Contamination in Streams and Ground Water* (Chapter 2, Purer Water), revealed that all the streams sampled by the NAWQA program had one or more contaminants at detectable levels throughout the year, and 85 percent had five or more (The Heinz Center, 2002).[13] Three-fourths of the streams tested had one or more contaminants that exceeded aquatic life guidelines. One-fourth of the streams exceeded the standards for four or more contaminants. Nearly all of the stream sediments tested had an average of five or more contaminants (PCBs, polycyclic aromatic hydrocarbons [PAHs], other industrial chemicals and trace elements) at detectable levels, and half had one or more contaminants that exceeded aquatic life guidelines. Half of the fish tested had at least five contaminants (PCBs, organochlorine pesticides, and trace elements) at detectable levels, and approximately the same number had one or more contaminants at levels that exceeded the aquatic life guidelines (The Heinz Center, 2002).[14]

- The indicator *Acid Sensitivity in Lakes and Streams* (Chapter 2, Purer Water) is affected by the natural buffering capacity of the soil and the rate of acid deposition from the atmosphere. The National Surface Water Survey (NSWS) (Landers, et al., 1988; Linthurst, et al., 1986; Messer, et al., 1986, 1988) determined that 4.2 percent of the NSWS lakes and 2.7 percent of NSWS streams were acidic (Acid Neutralizing Capacity <0 μeq/L) (Baker, et al., 1991). Almost 20 percent (19.1 percent) of NSWS lakes and 11.8 percent of NSWS streams were susceptible to acidic deposition (ANC < 50 μeq/L) (Baker, et al., 1991).[15] Of the acidic NSWS lakes, 75 percent were classified as acidic from acid deposition, 22 percent were organic acid dominated, and 3 percent were acidic from watershed sulfur sources. Of the acidic stream reaches, 70 percent were acidic from acid deposition, 29 percent were organic acid dominated, and 1 percent were acidic from watershed sulfur sources (Baker, et al., 1991).

  These surveys have been repeated periodically for smaller probability samples of lakes in the Northeast, the Adirondacks, and streams in the Appalachians (Stoddard, et al., 1996). More intensive monitoring also has been conducted on lakes in the Northeast, the Appalachians, and the Midwest, and on streams in the Appalachian Plateau and Blue Ridge to assess long-term acidification trends (Stoddard, et al., 1998). Based on these

[12] Concentrations in parentheses represent the 95 percent confidence interval.

[13] Nitrate, ammonium, and trace metals were not included in the occurrence analysis, because they occur naturally (Heinz(The HeinzCenterHeinz Center, 2002, p.50).

[14]Additional information on chemical contamination in all waters of the U.S. is provided in the technical notes, pp. 210-214, of the Heinz report (2002).

[15]There were regional differences in these percentages: only 0.1 percent of NSWS lakes in the West and Florida were sensitive, but 22.7 percent of Northern Appalachian streams were sensitive.

programs, EPA estimated that in three regions, one-quarter to one-third of lakes and streams previously affected by acid rain were no longer acidic, although they were still highly sensitive to future changes in deposition (EPA, ORD, January 2003). Specifically:

- Eight percent of lakes in the Adirondacks are currently acidic, down from 13 percent in the early 1990s.
- Less than 2 percent of lakes in the Upper Midwest are currently acidic, down from 3 percent in the early 1980s.
- Nine percent of the stream length in the Northern Appalachian Plateau region is currently acidic, down from 12 percent in the early 1990s.

Lakes in New England registered insignificant decreases in acidity, and streams in the Ridge and Blue Ridge regions of Virginia were unchanged. The Ridge and Blue Ridge regions are expected to show a lag time in their recovery due to the nature of their soils, and immediate responses to decreasing deposition were neither seen nor expected. The NSWS has not been repeated nationwide, so no data exist to assess trends in surface water acidification in other sensitive areas of the country.

- The indicator *Changing Stream Flows* is one of two indicators presented in Chapter 2, Purer Water that are associated with fresh water hydrology and geomorphology and relate to the ecological condition of fresh water. Changes in stream flow can result in significant effects on fish habitat and chemical concentrations in streams. According to The Heinz Center (2002), the percentage of streams and rivers with major changes in the high or low flows or timing of those flows increased slightly from the 1970s to the 1990s, but the number with high flows well above the high flows between 1930 and 1949 increased by approximately 30 percent in the 1990s. The earlier 1930 through 1949 period included some droughts, but much of it also preceded widespread dam-building and irrigation projects.
- The greatest stressor to mid-Atlantic streams, and many other streams throughout the U.S., is altered instream habitat (EPA, ORD, Region 3, August 2000). A *Sedimentation Index* (Chapter 2, Purer Water) was developed for Mid-Atlantic Highland streams to assess the quality of instream habitat for supporting aquatic communities (Kaufmann, et al., 1999). The amount of fine sediments on the bottom of each stream was compared with expectations based on each stream's ability to transport fine sediments downstream (a function of the slope, depth and complexity of the stream). When the amount of fine sediments exceeds expectations, it suggests that the supply of sediments from the watershed to the stream is greater than what the stream can naturally process. Streams with levels of fine particles at least 10 percent below the predicted value were rated to be in "good" condition relative to the sedimentation criteria. Those with levels from 10 percent below to 20 percent above the predicted value were rated "fair." Those with levels more than 20 percent above regional mean expectations were rated "poor." Based on the Sedimentation Index, about 35 percent of the stream miles had good instream habitat, 40 percent had fair instream habitat, and 25 percent of the stream miles had poor instream habitat (EPA, ORD, Region 3, August 2000).

Several indicators presented for the first time in this report are described below. They include a Category 1 indicator related to landscape condition and six Category 2 indicators relating to biotic condition. There were no indicators for ecological processes or natural disturbance regimes.

Indicator | Extent of ponds, lakes, and reservoirs - Category I

This indicator reports the area of ponds, lakes, and reservoirs in the conterminous U.S., excluding the Great Lakes. Over the long term, changes in this indicator reflect the effects of climate on water levels in existing lakes, ponds, and reservoirs, and of reservoir construction, destruction, and management.

What the Data Show

The Heinz Center (2002) reports that, excluding the Great Lakes, the conterminous U.S. contains 21 million acres of lakes, ponds, and reservoirs. The number of ponds (small water bodies usually less than 20 acres and 6 feet deep) increased by 100 percent since the 1950s (Exhibit 5-25). For unknown reasons, the rate of lake and reservoir creation declined 43 percent from the 1970s to 1980s; deep water lakes and reservoirs showed a modest but statistically unreliable increase between the 1980s and 1990s (Dahl, 2000).

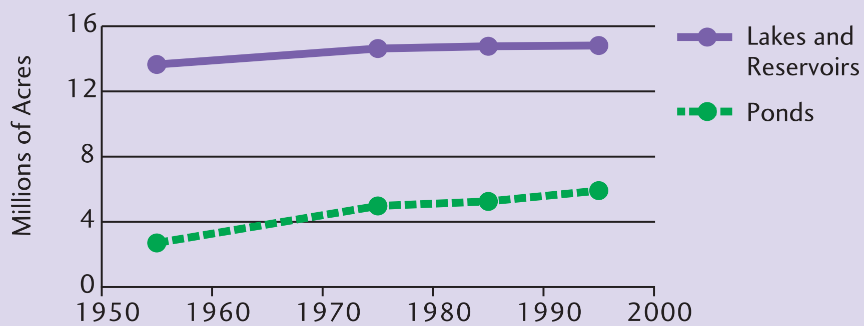
Indicator Gaps and Limitations

The USGS National Hydrography Dataset identifies a considerably larger area of lakes, reservoirs, and ponds at least 6 acres in size (26.8 million acres), and the cause of the discrepancy is unknown (The Heinz Center, 2002).

Data Source

The data source for this indicator was the National Wetlands Inventory, U.S. Fish and Wildlife Service (1970-2000). (See Appendix B, page B-43 for more information.)

Exhibit 5-25: Extent of ponds, lakes, and reservoirs, 1950s-1990s



Coverage: lower 48 states.

Note: Lake area does not include the Great Lakes, which cover about 60.2 million acres within the United States.

Source: The Heinz Center. *The State of the Nation's Ecosystems.* 2002. Data from the U.S. Fish and Wildlife Service's National Wetlands Inventory.

Indicator At-risk fresh water native species - Category 2

The U.S. was sufficiently concerned about preserving species to enact the Endangered Species Act in 1973 to provide legal protection for species that were endangered or threatened. Many of these species depend on lakes, streams, and adjoining wetlands for their continued existence. It is impossible to monitor all freshwater species, but this indicator reports on species of fish, amphibians, reptiles, aquatic mammals, butterflies, mussels, snails, crayfish, fresh water shrimp, dragonflies, damselflies, mayflies, stoneflies, and caddisflies that are at various degrees of risk of extinction (The Heinz Center, 2002).

What the Data Show

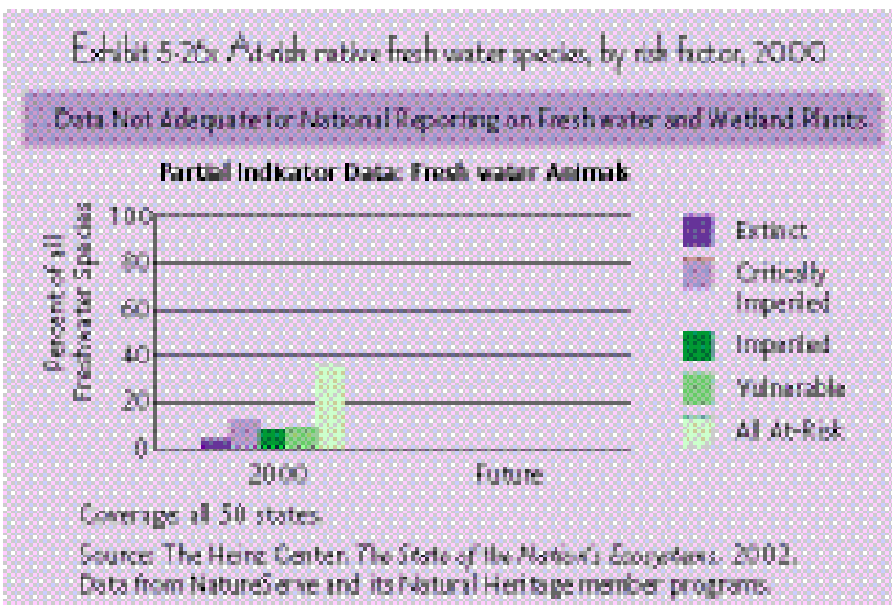
According to The Heinz Center (2002), approximately 13 percent of native fresh water species are critically imperiled, 8 percent are imperiled, 11 percent are vulnerable, and 4 percent are or might be extinct (Exhibit 5-26). Critically imperiled species are typically found at no more than five places, and may have suffered steep declines or very high risk. Vulnerable species may be found in 20 to 80 locations and show widespread declines or moderate levels of risk (Stein, 2002). Mussels and fish are particularly at risk. Hawaii and the Southeast have significantly higher percentages of at-risk species than other regions, but this condition may be partially the result of Hawaii and parts of the Southeast having a higher number of naturally rare species (The Heinz Center, 2002).

Indicator Gaps and Limitations

The data underlying this indicator are not from a site-based monitoring program, but rather from a census approach that focuses on the location and distribution of at-risk species. The data do not distinguish species that are naturally rare from species that have become rare because of human actions, making it difficult to distinguish actual trends in this indicator.

Data Source

The data source for this indicator was *The State of the Nation's Ecosystems,* The Heinz Center, 2002, using data from NatureServe Explorer database. (See Appendix B, page B-43, for more information.)



Indicator | Non-native fresh water fish species - Category 2

This indicator reports on the percentage of watersheds with different numbers of non-native species with established breeding populations (The Heinz Center, 2002). Non-native species include species not native to North America and species that are native to this continent but are now found outside their historic range. Such species, once introduced from some other location, often lack predators or parasites that kept them in check in their native habitats, and expand to cause a degree of ecological and economic disruption. Some non-native species are introduced intentionally (e.g., rainbow trout).

What the Data Show

Data are currently available nationally only for fish: of 350 watersheds (6-digit HUCs) in the U.S., only five have no non-native fish (The Heinz Center, 2002). Sixty percent have 1 to 10 non-native species, and two watersheds have 41 to 50 non-native fish species (Exhibit 5-27).

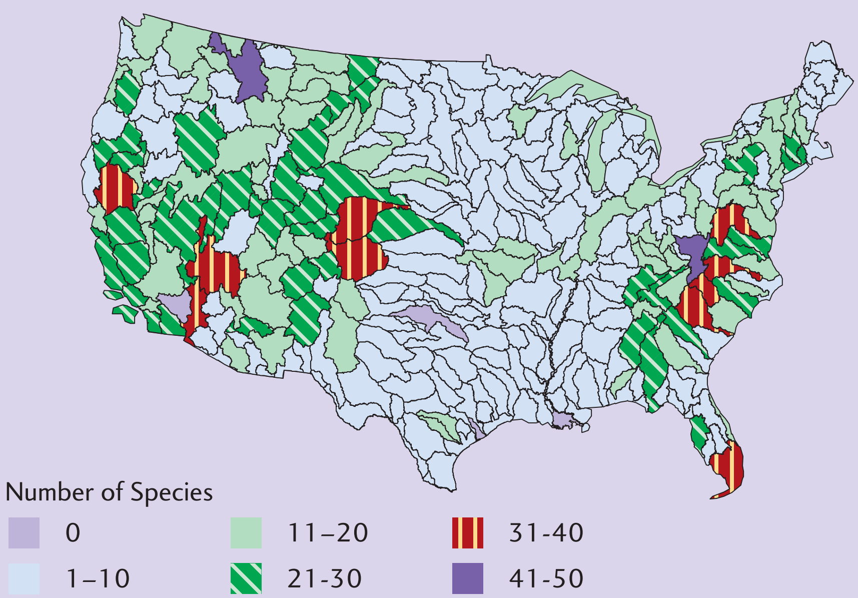
Indicator Gaps and Limitations

The data are not from a site-based monitoring program; they rely for the most part (90 percent) on the published literature and (10 percent) direct reporting by governmental and private biologists. New discoveries are not always reported (The Heinz Center, 2002).

Data Source

The data source for this indicator was The *State of the Nation's Ecosystems,* The Heinz Center, 2002, using data from the Non-indigenous Aquatic Species database. (See Appendix B, page B-44, for more information.)

Exhibit 5-27: Non-native fresh water fish species, 2000



Coverage: lower 48 states.

Source: The Heinz Center. *The State of the Nation's Ecosystems.* 2002. Data from the U.S. Geological Survey.

Indicator

Animal deaths and deformities - Category 2

Unusual mortality events (e.g., fish kills) or deformities (e.g., frog deformities) can have economic consequences, and they are also seen as evidence that something is wrong (e.g., a contaminant is present, or the organisms are under stress from some other source). Although data are collected on die-offs of mammals, fish, and amphibians, and on amphibian deformities, data are insufficient for national reporting (The Heinz Center, 2002). This indicator reports on unusual mortality events for waterfowl only.

What the Data Show

From 1995 to 1999, approximately 500 incidents of unusual waterfowl mortality were reported (The Heinz Center, 2002) (Exhibit 5-28). In slightly more than 20 percent of the incidents, more than 1,000 birds died, and in 15 of the incidents, more than 10,000 birds died. The total number of die-offs reported from 1995 to 1999 was 20 percent lower than the numbers reported in two earlier periods (1985 to 1989 and 1990 to 1994) (The Heinz Center, 2002). A larger number of events were reported in the Pacific and Midwest regions; fewer were reported in the Southwest and Southeast.

Indicator Gaps and Limitations

The data are not from a defined site-based monitoring program, but are provided by various sources such as state and federal personnel, diagnostic laboratories, wildlife refuges, and published reports, as they are discovered or reported (The Heinz Center, 2002). This makes it hard to distinguish real trends from trends in reporting.

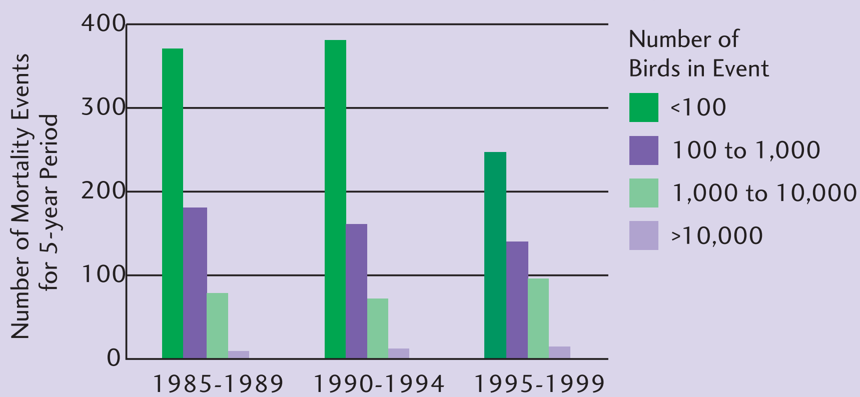
Data Source

The data source for this indicator was *The State of the Nation's Ecosystems,* The Heinz Center, 2002, using data from the National Wildlife Health Center database.
(See Appendix B, page B-44, for more information.)

Exhibit 5-28: Animal deaths and deformities, 1985-1999

Data Not Adequate for National Reporting on:
- Fish Die-offs
- Mammal Die-offs
- Amphibian Die-offs
- Amphibian Deformities

Partial Indicator Data: Waterfowl Mortality Only



Coverage: all 50 states, Puerto Rico, and the U.S. Virgin Islands

Source: The Heinz Center. *The State of the Nation's Ecosystems.* 2002. Data from the U.S. Geological Survey.

Indicator At-risk fresh water plant communities - Category 2

The Heinz report employs an indicator of the threat of elimination of wetland and riparian area plant communities. This indicator uses an expert assessment conducted by NatureServe (Stein, 2002) of factors such as the remaining number and condition of the community, the remaining acreage, and the severity of threats to the community type.

What the Data Show

According to this indicator, 12 percent of the 1,560 wetland communities ranked are critically imperiled, 24 percent are imperiled, and 25 percent are vulnerable (The Heinz Center, 2002) (Exhibit 5-29).

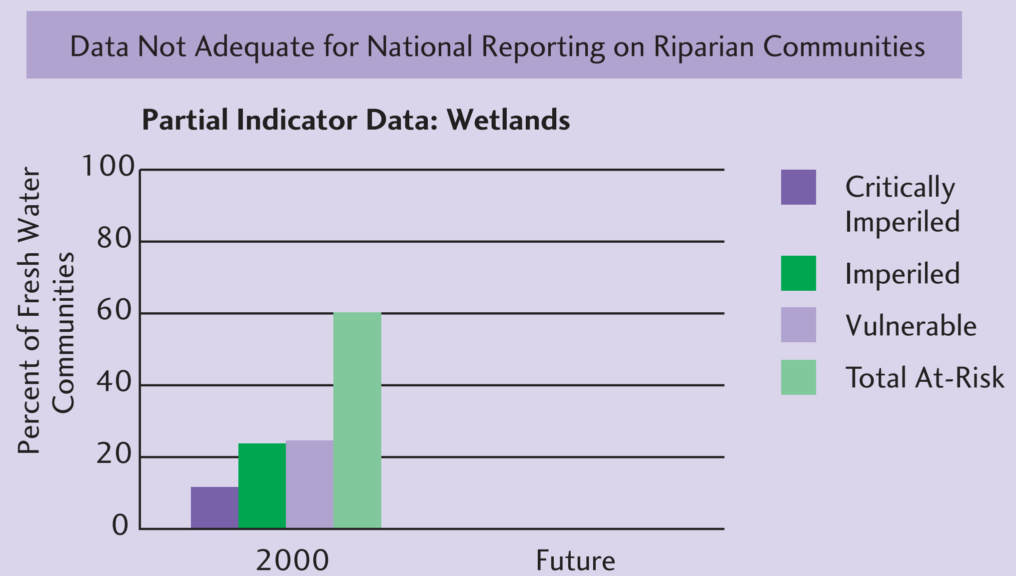
Indicator Gaps and Limitations

The Heinz report states that data are not adequate for national reporting (The Heinz Center, 2002). The report concludes that technical challenges in classifying riparian communities prevent national estimates for stream bank plant communities. In addition, interpreting the data is complicated because some species are naturally rare, and the total number of species for any ecosystem is unknown.

Data Source

The data source for this indicator was *The State of the Nation's Ecosystems,* The Heinz Center, 2002, using data from NatureServe Explorer database. (See Appendix B, page B-44, for more information.)

Exhibit 5-29: At-risk fresh water plant communities, 2000



Coverage: excludes Alaska.

Source: The Heinz Center. *The State of the Nation's Ecosystems.* 2002. Data from NatureServe and its Natural Heritage member programs.

Indicator Fish Index of Biotic Integrity in streams - Category 2

Fish communities integrate the effects of the physical, chemical, and biological stressors in the environment. The Heinz Center (2002) listed the status of fresh water animal communities as an indicator in need of development. Karr, et al. (1986, 1997) developed a Fish Index of Biotic Integrity (IBI) that incorporates species richness, trophic composition, reproductive composition, and abundance and individual health of fish communities in streams. This index, modified by McCormick, et al. (2001), was applied to a regional survey of streams in the mid-Atlantic states, and provides an example of an indicator that could be applied nationally.

A sample of reference sites that represented the best conditions observable today in the mid-Atlantic region (e.g., sites free of influences from mine drainage, nutrients, habitat degradation) provided a frame of reference for ranking the condition of streams overall. The IBI scores calculated for the reference sites ranged from 57 to 98. The 25th percentile of this distribution (IBI=72) was used to distinguish sites that were in good condition from those in fair condition. The first percentile value (IBI=57) separated sites in fair condition from those in poor condition. A statistical way to describe this setting of thresholds is to say that any IBI score of less than 57 in a sampled stream is 99 percent certain to be below the range of values seen in reference sites (McCormick, et al., 2001).

What the Data Show

Fish were collected at probability sites that represent about 90,000 miles of streams in the mid-Atlantic. The fish IBI indicated that 27 percent of the streams were in good condition and 14 percent were in poor condition in the Mid-Atlantic Highlands (see Exhibit 5-30). About 38 percent of the streams were scored in fair condition. No fish were caught in about 21 percent of the streams. The estimates of stream condition have a confidence interval of about ±.8 percent (McCormick, et al., 2001).

Indicator Gaps and Limitations

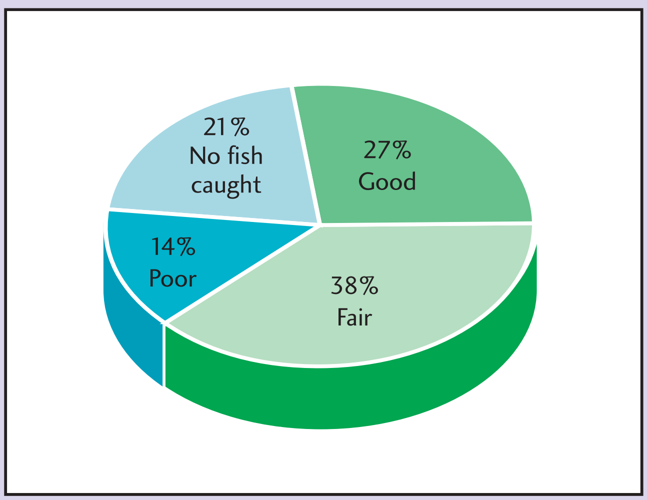
The limitations of this indicator include the following:

- Condition cannot be assessed in streams where no fish were caught. Poor condition cannot be inferred from no fish caught, because some streams were likely too small to support a fishery. Data were insufficient to indicate if the stream had poor quality or simply no fish (EPA, ORD, Region 3, August 2000).
- The data are available only for a limited geographic region, and no repeated sampling is available to estimate trends.

Data Source

The data source for this indicator was the Mid-Atlantic Highlands Streams Assessment, Environmental Protection Agency, August 2000, using data from the Mid-Atlantic Integrated Assessment. (See Appendix B, page B-45, for more information.)

Exhibit 5-30: Fish Index of Biotic Integrity (IBI) indicators used to assess stream condition in the Mid-Atlantic Highlands, 1993-1996



Coverage: Mid-Atlantic Highlands

Note: No fish caught does not indicate poor condition. Some streams naturally do not have fish.

Source: McCormick, F. H. et al. *Development of an Index of Biotic Integrity for the Mid-Atlantic Highlands Region.* 2001.

Indicator Macroinvertebrate Biotic Integrity Index for streams - Category 2

Like fish, macroinvertebrate communities integrate physical, chemical, and biological stressors, but because many of them are more sedentary than fish and occupy different ecological niches, they provide a complementary picture of ecological condition.

A Macroinvertebrate Biotic Integrity Index (MBII) was developed for mid-Atlantic streams by Klemm, et al. (2002, 2003). The MBII incorporates taxa richness, assemblage composition, pollution tolerance (includes all maroinvertebrates, not just insects), and functional feeding groups (Klemm, et al., 2002). Similar to the approach used to separate the Fish IBI scores (McCormick, et al., 2001), the 25th percentile of the reference site MBII scores was used to distinguish sites in good condition from those in fair condition. The first percentile was used to separate sites in fair condition from those in poor condition (McCormick, et al., 2001).

What the Data Show

The MBII scores indicated that 17 percent of the streams in the mid-Atlantic were in good condition, 57 percent were in fair condition, and 26 percent were in poor condition (Exhibit 5-31).

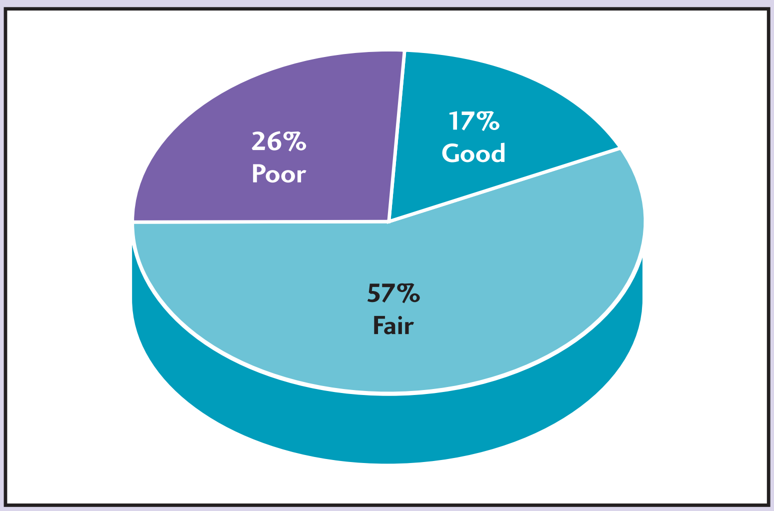
Indicator Gaps and Limitations

The data are available only for a limited geographic region, and no repeated sampling is available to estimate trends.

Data Source

The data source for this indicator was *Development and Evaluation of a Macroinvertebrate Biotic Integrity Index (MBII) for Regionally Assessing Mid-Atlantic Highlands Streams.* 2003, Klemm, et al., using data from the Mid-Atlantic Integrated Assessment. (See Appendix B, page B-45, for more information.)

Exhibit 5-31: Macroinvertebrate Biotic Integrity Index (MBII), Mid-Atlantic Highlands, 1993-1996



Coverage: Mid-Atlantic Highlands

Source: Klemm, D.J., et al. *Development and Evaluation of a Macroinvertebrate Biotic Integrity Index (MBII) for Regionally Assessing Mid-Atlantic Highlands Streams.* 2003.

Summary: The Ecological Condition of Fresh Waters

Fresh water systems are under pressure from point and non-point pollution, atmospheric deposition, altered habitat, and invasive species. A review of Exhibit 5-24, however, indicates that there are virtually no Category 1 indicators or monitoring programs that provide a national picture of the ecological condition of fresh waters. No national condition data are available on ecological processes, not are there any nationally or regionally reported indicators of natural disturbance regimes.

Landscape condition

The National Wetlands Inventory provides unbiased statistical estimates of the extent of wetlands, ponds, lakes, and reservoirs in the conterminous U.S. at decadal scales since the 1970s. There is no similar effort for the extent of streams (losses can occur because of mining, damming, water withdrawal, or climate change). Chapter 2, Purer Water, estimates that the U.S. has more than 3.7 million miles of streams and rivers (EPA, OW, June 2000a, 2000b). About 60 percent of all these stream miles are found in small, headwater streams. The Heinz Center reports, however, that because there is no agreed-upon system to classify streams (e.g., by discharge, drainage area, or stream order), there are no national data sets for reporting on stream size.

Biotic condition

At this time, no national condition data are available on lake, wetland, or stream biota. The USGS National Water Quality Assessment (NAWQA) program has collected data on the biota in rivers and streams in the network, but no analysis has been performed on the data at a national level (USGS, 2002; <http://water.usgs.gov/nawqa/>). Surveys of stream benthos and fish communities have been conducted for the mid-Atlantic region that provide unbiased estimates of the condition of 90 percent of the streams in the region. Both surveys showed only 17 percent (±8 percent) of the streams to be in good condition, but there is no indication of whether they are the same streams or of the likely cause(s) of impairment. No fish were caught in 16 percent of the streams, so their condition could not be judged based on this criterion. Similar regional studies have been conducted in the western states, but the data have not yet been reported. There are no nationally or regionally representative data on the aquatic communities of lakes. Based on NatureServe data, 36 percent of aquatic biota in several categories are either extinct or at some risk of extinction, but because this database relies on voluntary reporting, future trends might not be discernable with statistical reliability. NAWQA collected contaminant data from fish tissue in 223 streams, and almost half showed concentrations that exceeded aquatic life guidelines for at least one contaminant. However, these data have not been related to the condition of the fish communities in the corresponding streams, so ecological condition cannot be determined. There are no specific plans to re-sample in any of these programs, and so there is no assurance that trend data will be available in the future.

Chemical and physical characteristics

Better data are available for chemical and physical characteristics of streams, less for lakes, and none for wetlands. The NAWQA program reports data on total phosphorus concentrations in more than 140 large rivers nationwide, but there are no corresponding national data on either lake or reservoir concentrations (where algal blooms are likely to develop), nor on the corresponding biological communities. Reliable regional estimates have been made of total phosphorus concentrations in 11,076 lakes in the Northeast states. These estimates showed with a high degree of confidence that fewer than 22 percent of the lakes were estimated to be eutrophic or hypertrophic. While a relationship exists between total phosphorus concentrations and algal biomass or productivity (Carlson, 1977), lake-to-lake variation is considerable, so none of these data truly express the known ecological condition of these lakes or rivers with respect to eutrophication. Nitrate is not often a limiting nutrient in fresh waters, so it provides little ecological information on fresh waters themselves (although it does provide useful information on the watershed, as discussed in the sections on forests and farmlands).

The NAWQA program reports on contaminants in stream waters from 109 streams, and sediments from 558 stream sites across the U.S. At least half of the streams had concentrations that exceeded wildlife criteria, but there are as yet no analyses relating these to the condition of fish or invertebrate communities in the streams naturally. Incorporation of water quality data monitored by the states could improve the coverage, if care is given to representative sampling and comparable methods and indicators.

A national survey in the 1980s provided estimates of the sensitivity of all lakes and all streams in the eastern U.S. to acidic deposition (Landers, et al., 1988; Kaufmann, et al., 1991). Periodic resurveys and intensive sampling of representative lakes and streams have allowed EPA to conclude that, because of reductions in sulfate emissions under its acid rain regulations, one-quarter to one-third of lakes and streams in three regions affected by acid rain are no longer acidic (EPA, ORD, Region 3, August 2000). Corresponding biological community data exist only for streams in the Mid-Atlantic Highlands.

Hydrology and geomorphology

There are nationally reported data on only one hydrologic/geomorphological indicator: changing stream flow. This indicator is reported on all rivers and streams for which the record of data is adequate, and it shows that high flows have increased during the past decade. There are no corresponding data to indicate why, however, nor are there data on any accompanying change in the fish communities, so ecological condition cannot be assessed with any reliability.

There were no Category 1 or 2 indicators available for *ecological processes* or *natural disturbance regimes* for fresh waters. Limnologists have long measured primary productivity in lakes, and nutrient spiraling and leaf-pack decomposition in streams, but no systematic data were available in the form of an indicator for this report. Phenomena involved in natural disturbance regimes in fresh waters include hydrology (e.g., low-flow frequencies, floods), time of ice-out in lakes, and fires and other factors that affect watersheds.

5.7 What Is the Ecological Condition of Coasts and Oceans?

The coasts and oceans of the United States extend from the shoreline out approximately 200 miles into the open ocean. The indicators in this report, however, focus on estuaries and coastal waters within 25 miles of the coast. Coastal ecosystems are productive and diverse, and include estuaries, coastal wetlands, coral reefs, mangrove forests, and upwelling areas. Critical coastal habitats provide spawning grounds, nurseries, shelter, and food for finfish, shellfish, birds, and other wildlife. Coastal areas are also sinks for pollutants transported through surface water, ground water, and atmospheric deposition.

Coastal areas are among the most developed areas in the nation. Coastal areas comprise 17 percent of total conterminous U.S. land area, yet these areas are home to 53 percent of the U.S. human population. The coastal population is increasing by about 3,600 people per day, giving rise to a projected total increase of 27 million people between 2000 and 2015 (U.S. Census Bureau, 2002).

Coastal areas also contribute significantly to the U.S. economy. Almost 31 percent of the Gross National Product is produced in coastal counties (EPA, ORD, OW, September 2001). Almost 85 percent of commercially harvested fish depend on estuaries and adjacent coastal waters at some stage in their life cycle (NRC, 1997). About 180 million people use coastal beaches each year (Cunningham and Walker, 1996). Estuaries supply water, receive discharge from municipal and industrial sources, and support agriculture, commercial and sport fisheries, and recreational uses such as swimming, and boating.

National estuarine and coastal monitoring programs have been in place for 15 to 20 years. A number of agencies and programs provide information on the condition of coastal waters and wetlands, including the National Oceanic and Atmospheric Administration's (NOAA) National Status and Trends Program, National Estuarine Research Reserve System, and National Marine Fisheries Service National Habitat Program; EPA's National Estuary Program and Environmental Monitoring and Assessment Program; and the Fish and Wildlife Service National Wetlands Inventory and Coastal Program.

In 2000, EPA, NOAA and USGS, in cooperation with all 24 U.S. coastal states, initiated the National Coastal Assessment (also known as Coastal 2000 or C2000). Using a compatible, probabilistic design and a common set of survey indicators, each state conducted

Exhibit 5-32: Coasts and oceans indicators

Essential Ecological Attribute	Indicators	Category		Source
Landscape Condition		I	II	
Extent of Ecological System/Habitat Types	Extent of estuaries and coastline	■		EPA
Landscape Composition	Coastal living habitats		■	DOI
	Shoreline types		■	DOC
Landscape Structure/Pattern				
Biotic Condition				
Ecosystems and Communities	Benthic Community Index		■	EPA
	Fish diversity		■	EPA
	Submerged aquatic vegetation		■	EPA
Species and Populations	Chlorophyll concentrations		■	EPA
Organism Condition	Fish abnormalities		■	EPA
	Unusual marine mortalities		■	DOC
Ecological Processes				
Energy Flow				
Material Flow				
Chemical and Physical Characteristics				
Nutrient Concentrations	Total nitrogen in coastal waters		■	EPA
	Total phosphorous in coastal waters		■	EPA
Other Chemical Parameters	Dissolved oxygen in coastal waters		■	EPA
	Total organic carbon in sediments		■	EPA
Trace Organics and Inorganics	Sediment contamination of coastal waters		■	EPA
	Sediment toxicity in estuaries		■	EPA
Physical Parameters	Water clarity in coastal waters		■	EPA
Hydrology and Geomorphology				
Surface and Ground Water Flows				
Dynamic Structural Conditions				
Sediment and Material Transport				
Natural Disturbance Regimes				
Frequency				
Extent				
Duration				

Note: MAIA indicators included pending completion of peer review the survey and independently assessed the condition of their coastal resources. These estimates currently are being aggregated to assess the condition of the nation's coastal waters. While the first complete assessment of the nation's coastal waters will be available in 2003, a preliminary assessment of selected estuarine systems was published in 2001 (EPA, ORD, OW, September 2001).

Exhibit 5-32 lists the ecological indicators of coastal condition used in this report. Eight indicators are discussed in Chapter 2, Purer Water. The indicator *Chlorophyll Concentrations* deals with biotic structure of phytoplankton communities, and the rest are associated with the chemical and physical characteristics of coastal ecosystems. These eight indicators are summarized below. The section then presents nine indicators that appear for the first time in this report. Two involve the coastal landscape, and the rest involve the biotic structure of coastal ecosystems. There are no indicators of ecological processes, hydrology and geomorphology, or natural disturbance regimes with data suitable for national or regional reporting.

The following indicators presented in previous chapters relate to the ecological condition of coasts and oceans:

- The indicator *Chlorophyll Concentrations* is a measure of the abundance of phytoplankton. Excessive growth of phytoplankton, as measured by chlorophyll concentrations, can lead to degraded water quality, such as noxious odors, decreased water clarity, andoxygen depletion. Excess phytoplankton growth is usually associated with increased nutrient inputs (e.g., watershed or atmospheric transport, upwelling) or a decline in filtering organisms such as clams, mussels, or oysters (The Heinz Center, 2002).

  Average seasonal ocean chlorophyll concentrations (within 25 miles of the coast) ranged from 0.1 to 6.5 ppb (The Heinz Center, 2002). The highest ocean chlorophyll concentrations (4.8 to 6.5 ppb) were in the Gulf of Mexico with the lowest concentrations in Hawaiian waters (0.1 ppb). Southern California had the next lowest chlorophyll concentrations, between 1.1 and 1.5 ppb. Other ocean waters (e.g., north, mid-, and south Atlantic, and Pacific Northwest) had chlorophyll concentrations ranging from 2 to 4.5 ppb.

  Estuarine chlorophyll concentrations were not available for national reporting in the Heinz report, but chlorophyll concentrations in the mid-Atlantic estuaries ranged from 0.7 to 95 ppb in 1997 and 1998 (EPA, ORD, May 2003). EPA established three categories: good <15 ppb; fair 15-30 ppb; and poor >30 ppb. The lower threshold of 15 ppb chlorophyll is equal to the restoration goal recommended for the survival of submerged aquatic vegetation (SAV) in the Chesapeake Bay (Batiuk, et al., 2000). About 33 percent of the mid-Atlantic estuarine area had chlorophyll concentrations exceeding 15 ppb. The Delaware Estuary showed a wide range of chlorophyll concentrations, from low in the Delaware Bay (<15 ppb) to intermediate in the Delaware River (15 to 30 ppb) to very high (>80 ppb) in the Salem River. The western tributaries to the Chesapeake Bay were consistently high in chlorophyll, with more than 25 percent of the area showing >30 ppb chlorophyll concentrations. Chlorophyll concentrations in the coastal bays were generally low (< 15 ppb), even though nutrients were elevated, because of increased turbidity and low light penetration.

- The *Water Clarity in Coastal Waters* (Chapter 2, Purer Water) indicator is important for maintaining productive systems in good condition and is affected by chlorophyll concentrations. Light penetration is important for submerged aquatic vegetation (SAV), which serves as food, nursery, shelter, and refugia habitat (areas that provide protection from predators) for aquatic organisms. EMAP measured water clarity using a light penetrometer, which recorded the amount of surface light that penetrated to a depth of 1 meter (EPA, ORD, OW, September 2001). Water clarity was considered poor if less than 10 percent of surface radiation penetrated to 1 meter. Water clarity was considered fair if there was between 10 and 25 percent penetration, and clarity was considered good if there was greater than 25 percent penetration. Data were collected for all conterminous estuaries in the U.S. The 10 percent light penetration at 1 meter is required to support SAV, which is an ecological endpoint in several estuarine ecosystems. Overall, 64 percent of the nation's estuarine area had light penetration of at least 25 percent at 1 meter (EPA, ORD, OW, September 2001). Only 4 percent of the nation's estuarine area had poor light penetration (less than 10 percent).

- Nitrogen, and less often phosphorus, control the chlorophyll concentrations in coastal ecosystems. The indicator *Total Nitrogen in Coastal Waters* (Chapter 2, Purer Water), was calculated for the mid-Atlantic estuaries by summing the concentrations of total dissolved nitrogen and particulate organic nitrogen (EPA, ORD, May 2003). Assessment categories were determined based on the 25th and 75th percentiles because there are no total nitrogen (TN) criteria for estuaries. The categories are: low < 0.5 ppm N; intermediate 0.5 to 1.0 ppm N; and high > 1.0 ppm N. About 35 percent of the mid-Atlantic estuarine area had low TN concentrations, 47 percent had intermediate TN concentrations, and 18 percent had high TN concentrations. About 50 percent of the mainstem area of the Chesapeake Bay had low TN concentrations, with only about 5 percent having high TN concentrations. The coastal bays, in contrast, had about 5 percent of their area with low TN concentrations and about 35 percent with high TN concentrations. The Delaware River estuary portion of Delaware Bay had 100 percent of its area with high TN concentrations.

- The indicator *Total Phosphorus in Coastal Waters* (Chapter 2, Purer Water) assessment categories were based on the 25th and 75th percentile concentrations measured throughout the mid-Atlantic. These categories are: low < 0.05 mg P/L; intermediate 0.05 to 0.1 mg P/L; and high > 0.1 mg P/L. Total phosphorus (TP) concentrations ranged from 0 to 0.34 mg P/L. About 58 percent of the mid-Atlantic estuarine area had low TP concentrations, 30 percent had intermediate, and 12 percent had high TP concentrations (EPA, ORD, May 2003). About 85 percent of the mainstem area of the Chesapeake Bay had low TP concentrations, with no areas having high TP concentrations. The coastal bays, in contrast, had no areas with low TP concentrations and about 35 percent with high TP concentrations. The Delaware River estuary portion of Delaware Bay had 100 percent of its area with high TP concentrations.

- Dissolved oxygen is depleted when phytoplankton in estuaries die and decompose. Data on the *Dissolved Oxygen in Coastal Waters* indicator (Chapter 2, Purer Water) were reported primarily for estuaries in the Virginian, Carolinian, and Louisianian Provinces[16]. Dissolved oxygen in these estuaries was reported as good because 80 percent of estuarine waters assessed were estimated to exhibit dissolved oxygen at concentrations greater than 5 ppm (EPA, ORD, OW, September 2001). Hypoxia resulting from anthropogenic activities is a relatively local occurrence in Gulf of Mexico estuaries; only 4 percent of the combined bottom areas in these estuaries is hypoxic. The occurrence of hypoxia in the shelf waters of the Gulf of Mexico is more significant. The Gulf of Mexico hypoxic zone is the largest area of anthropogenic coastal hypoxia in the western hemisphere (CAST, 1999). Since 1993, mid-summer bottom water hypoxia in the Northern Gulf of Mexico has been larger than 3,860 square miles and in 1999, it reached over 7,700 square miles (CENR, 2000).
- *Total Organic Carbon in Sediments* (Chapter 2, Purer Water) is often an indicator of organic pollution (e.g., from decomposing phytoplankton blooms or waste disposal). Total organic carbon (TOC) values are calculated as percent carbon in dried sediments. Values ranged from 0.02 to 13 percent carbon (Paul, et al. 1999). Assessment categories for the mid-Atlantic estuaries were tentatively set at: low 1 percent; intermediate 1 to 3 percent, and high >3 percent, but they are still under evaluation. For the mid-Atlantic region, about 60 percent of the sediments had low TOC values, about 24 percent had intermediate TOC values, and 16 percent had high sediment TOC values (EPA, ORD, May 2003). Values ranged from those of Delaware Bay, with about 95 percent of its sediments having low TOC values, to those of the Chowan River in the Albemarle-Pamlico Estuary with 65 percent of its sediments having high TOC values (EPA, ORD, May 2003). The Chesapeake Bay mainstem had about 65 percent of its sediments with low TOC values and about 15 percent with high TOC values.
- The *Sediment Contamination of Coastal Waters* indicator (Chapter 2, Purer Water) was analyzed in estuaries primarily along the Atlantic Coast and Gulf of Mexico as part of the EPA EMAP Estuaries Program. Results from these analyses indicated that 40 percent of estuarine sediments in these areas were enriched in metals from human sources, 45 percent were enriched in PCBs, and 75 percent were enriched in pesticides (EPA, ORD, OW, September 2001). The highest concentrations of all three constituents were found in South Florida sediments with 53 percent, 99 percent, and 93 percent of the sediment area enriched in metals, PCBs, and pesticides, respectively.
- The EPA EMAP Estuaries Program, in conjunction with the NOAA Status and Trends Program, developed the indicator S*ediment Toxicity in Estuaries* (Chapter 2, Purer Water). The EMAP Estuaries Program found that about 10 percent of the sediments in the Virginian, Carolinian, Louisianian, West Indian, and Californian Province estuaries were toxic to the marine amphipod *Ampelisca abdita* over a 10-day period (EPA, ORD, OW, September 2001). The NOAA Status and Trends Program also used a sea urchin fertility test and a microbial test to evaluate chronic toxicity in selected estuaries. NOAA found that 43 to 62 percent of the sediment samples from the selected estuaries showed chronic toxicity (EPA, ORD, OW, September 2001).

On the following pages, several indicators are introduced for the first time in this report that relate to the essential ecological attributes of landscape condition and biotic condition of estuaries.

[16] Provinces are biogeographical regions with distinct faunas.

Indicator Extent of estuaries and coastline - Category 1

Estuarine areas provide habitat for organisms which contribute significantly to the national economy. These areas also are under pressure from the 53 percent of the U.S. population that lives within 75 miles of the coast. Estuarine areas and coastline include brackish water bays and tidal rivers, which are influenced by the mixing of fresh water and ocean salt water in these areas. Extent estimates were provided by the coastal states as part of the EPA National Water Quality Inventory - 2000 Report (EPA, OW, August 2000).

What the Data Show

EPA estimates that the U.S. and its territories have 95.9 million acres of estuarine surface area and about 58,618 miles of coastline (EPA, OW, August 2002).

Indicator Gaps and Limitations

These data were compiled from inventories performed by the states. Differences in how each state defines estuaries are likely, so the consistency of the inventory is unknown.

Data Source

The data source for this indicator was the *2000 National Water Quality Inventory,* U.S. Environmental Protection Agency, August 2002. (See Appendix B, page B-45, for more information.)

Indicator Coastal living habitats - Category 2

This indicator provides the acreage of vegetative habitat such as submerged aquatic vegetation (SAV), mangrove forests, and coastal wetlands. Vegetation not only stabilizes the habitat, but also provides food, shelter, nursery areas, and refugia for other aquatic organisms. Loss of coastal habitat is a major contributor to the loss of both economic and non-marketable aquatic species (The Heinz Center, 2002).

What the Data Show

The USFWS National Wetlands Inventory (NWI) estimates more than 5 million acres of coastal wetlands contribute to the diversity of coastal habitat (Exhibit 5-33). Wetland acreage declined about 8 percent from the mid-1950s to the mid-1990s (The Heinz Center, 2002). Out of 5 million total acres, 400,000 acres of coastal wetland were lost over this period, although the loss rate declined in the 1990s (The Heinz Center, 2002).

Indicator Gaps and Limitations

Data for coral reefs and seagrasses and other SAV are available for many areas, but these data have not been integrated to produce a national estimate. Different approaches have been used to estimate some of these coastal habitats which make make integration difficult. For example, estimates of the extent of SAV are noted in some regions only as presence/absence, while the area is estimated quantitatively in other regions. Data for vegetated wetlands are available for only the East and Gulf Coasts.

Data Source

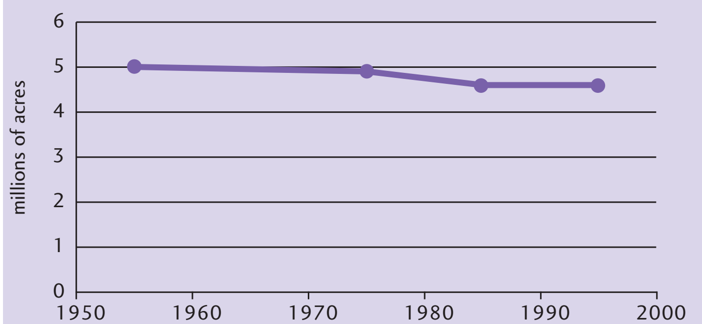
The data source for this indicator was *Status and Trends of Wetlands in the Conterminous United States 1986 to 1997*, Dahl, 2000, utilizing data from the National Wetlands Inventory. (See Appendix B, page B-45, for more information.)

Exhibit 5-33: Coastal living habitats, 1950s-1990s

Data Not Adequate for National Reporting on:

- Seagrasses/Submerged Vegetation
- Shellfish Beds
- Coral Reefs
- Wetlands in Other Regions

Partial Indicator Data: Coastal Vegetated Wetlands



Coverage: Atlantic and Gulf Coasts Only

Source: The Heinz Center. *The State of the Nation's Ecosystems.* 2002. Data from the U.S. Fish and Wildlife Service.

Indicator Shoreline types - Category 2

This indicator includes the miles of coastline in different categories, such as beaches, mud or sand flats, rock or clay cliffs, and wetlands. It also includes coastline that is protected with engineered structures such as armoring or riprap. Loss or conversion of shoreline habitat to armoring or riprap can eliminate the habitat required by various organisms for spawning, gestation, nursery area, feeding, or refugia.

What the Data Show

Over two-thirds of the mapped shoreline in the south Atlantic, southern California, and Pacific Northwest is coastal wetlands, with most of the coastal wetlands occurring in the South Atlantic (The Heinz Center, 2002) (Exhibit 5-34). Three-quarters of the south Atlantic shoreline is wetlands (The Heinz Center, 2002). Beaches account for about 33 percent of the shoreline in both southern California and the Pacific Northwest. Southern California, however, has a much lower percentage of wetlands and mud or sand flats than the Pacific Northwest. Steep shorelines, mud flats, and sand flats each make up the smallest portion of the total in all three regions. Armored shorelines, which inclde bulkheads and rip rap, account for about 11 percent of miles of the total coastline.

Indicator Gaps and Limitations

Estimates of shoreline types are not available for the entire U.S., including much of the Atlantic and Gulf Coast areas. Some of the atlases used to compile this information are more than 15 years old. Coastal areas are dynamic and change over time, so the accuracy of available estimates is unknown.

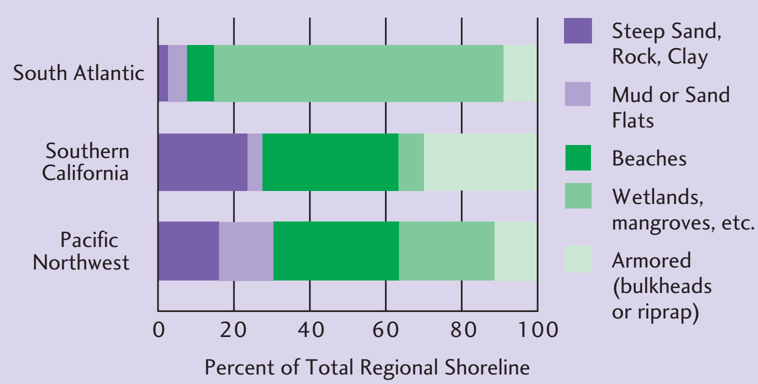
Data Source

The data source for this indicator was the *Environmental Sensitivity Index Atlases,* National Oceanic and Atmospheric Administration (1984-2001). (See Appendix B, page B-46, for more information.)

Exhibit 5-34: Coastal shoreline types, 2000

Data Not Adequate for National Reporting on:
- North Atlantic
- Mid-Atlantic
- Gulf of Mexico
- Gulf of Alaska
- Bering Sea
- Hawaii

Partial Indicator Data: Shoreline Types by Region



Coverage: Pacific Northwest, Southern California, and South Atlantic Regions only

Source: The Heinz Center. *The State of the Nation's Ecosystems.* 2002.
Data from the National Oceanic and Atmospheric Administration.

Indicator Benthic Community Index - Category 2

EMAP Estuaries Program has developed indices of benthic condition for estuaries in the conterminous U.S. (Engle and Summers, 1999; Engle, et al., 1994; Van Dolah, et al., 1999; Weisberg, et al., 1997). Benthic macroinvertebrates include annelids, mollusks, and crustaceans that inhabit the bottom substrates of estuaries. These organisms play a vital role in maintaining sediment and water quality, and are an important food source for bottom-feeding fish, invertebrates, ducks, and marsh birds. Measures of biodiversity and species richness, species composition, and relative abundance or productivity of functional groups are among the assemblage attributes that can be used to characterize benthic community composition and abundance. The Heinz report refers to this indicator as Condition of Bottom-Dwelling Organisms (The Heinz Center, 2002).

Assemblages of benthic organisms are sensitive to pollutant exposure (Holland, et al., 1987, 1988; Rhoads, et al., 1978; Pearson and Rosenberg, 1978; Sanders, et al., 1980; Boesch and Rosenberg, 1981), and they integrate responses to disturbance and exposure over relatively long periods of time (months to years). Their sensitivity to pollutant stress is, in part, because they live in sediment that accumulates environmental contaminants over time (Nixon, et al., 1986), and because they are relatively immobile.

Reference sites were used to calibrate the indices similar to the approach used to calibrate fish IBI scores in fresh water ecosystems. The references cited above describe the approaches used for calibration and scoring in various estuarine provinces. These indices were calibrated for the respective estuarine province in which they were developed. While the development and calibration process was similar among provinces, the specific thresholds reflect the estuarine conditions within that province. In general, good condition means that less than 10 percent of the coastal waters have low benthic index scores. Fair condition means that between 10 and 20 percent of the coastal waters have low benthic index scores. Poor condition means that greater than 20 percent of the coastal waters have low benthic index scores.

What the Data Show

Benthic community index scores have been assessed for the Northeast, Southeast, and Gulf Coastal Areas. For the Northeast, Southeast, and Gulf Coastal areas, 56 percent of the coastal waters were assessed in good condition, 22 percent in fair condition, and 22 percent in poor condition based on benthic index scores (Exhibit 5-35).

Associations of biological condition with specific stressors indicate that, of the 22 percent of coastal areas with poor benthic condition, 62 percent had sediment contamination, 11 percent had low dissolved oxygen concentrations, 7 percent had low light penetration, and 2 percent showed sediment toxicity (EPA, ORD, OW, September 2001).

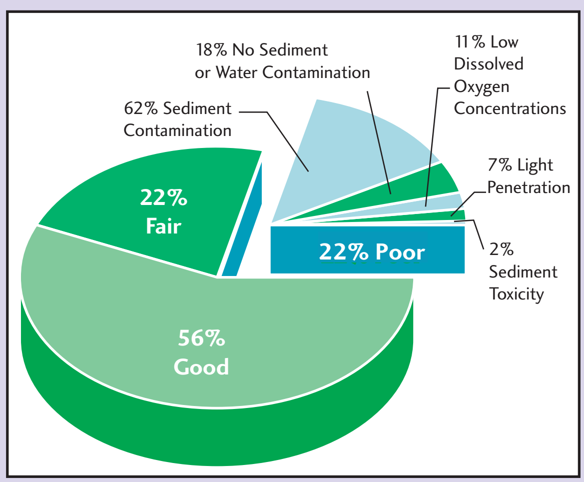
Indicator Gaps and Limitations

Benthic community index scores have been assessed only for the Northeast, Southeast, and Gulf Coastal areas. Samples have been collected in all coastal areas, including Alaska, Hawaii, and Island Territories, but these data have not been assessed. A complete assessment of coastal condition is anticipated in 2003.

Data Source

The data source for this indicator was *National Coastal Condition Report*, U.S. Environmental Protection Agency, September 2001, using data from the Environmental Monitoring and Assessment Program, Estuaries Program. (See Appendix B, page B-46, for more information.)

Exhibit 5-35: Benthic Community Index (BCI) scores for coastal waters in good, fair, or poor condition, 2000



Coverage: Northeast, Southeast, and Gulf Coastal areas

Source: EPA, Office of Research and Development and Office of Water. *National Coastal Condition Report.* September 2001.

Indicator | Fish diversity - Category 2

Fish diversity is considered to be an indicator of ecological condition because fish integrate effects of environmental stress over space and time (EPA, ORD, September 1998). For this indicator, fish collected by trawling are identified, enumerated, and measured, allowing assessment of native and non-native species, diversity, abundance, pollution-tolerant/intolerant, and size class (e.g., young-of-year and adults).

This indicator provides data for the mid-Atlantic estuaries. Because fish catch data are sensitive to different sampling gear, no critical thresholds were established for the mid-Atlantic estuaries. High and low diversity were arbitrarily established as: high > 3 fish species in a standard trawl; low ≤ 3 fish species in a standard trawl (EPA, ORD, May 2003).

What the Data Show

In 1998, out of 110 sampling sites selected for the mid-Atlantic estuaries in 1998, fish trawls were conducted at 80 sites (the others were too shallow to trawl). The fish species count ranged from 0 to 13, with an average of 4.6 species per site (Exhibit 5-36). For the mid-Atlantic estuaries in general, more fish species were found in upper Delaware Bay, the coastal bays, and in the upper portions of tributaries. Fewer species were evident in the Chesapeake Bay mainstem and lower tributaries.

Indicator Gaps and Limitations

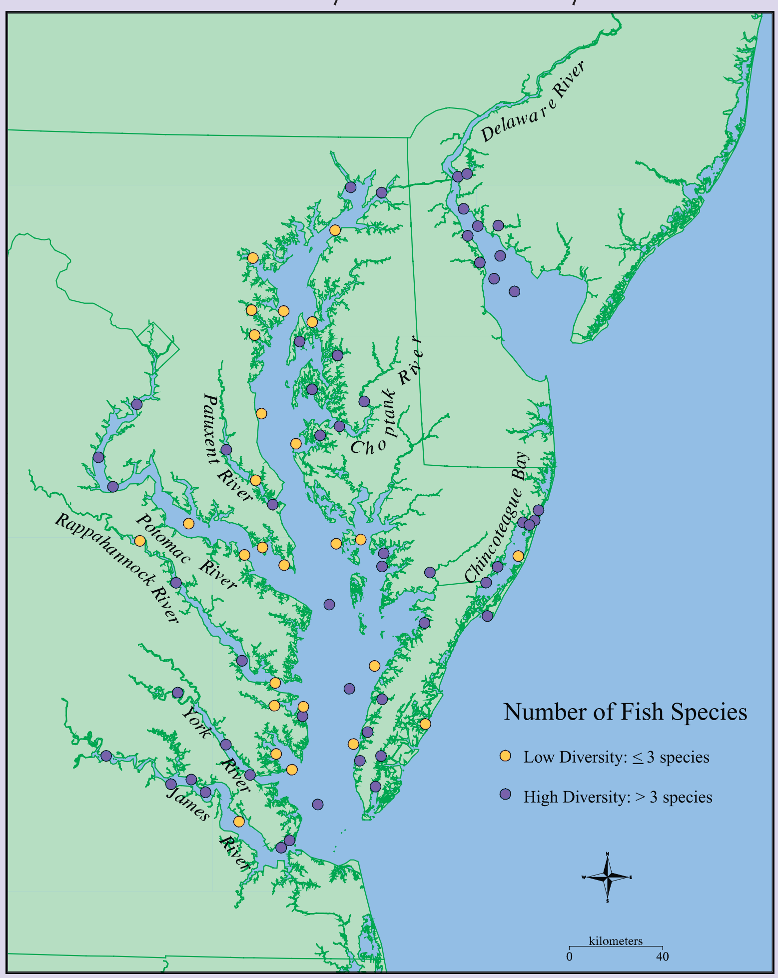
The limitations of this indicator include the following:

- Fish diversity estimates are available only for the mid-Atlantic estuaries.
- While fish diversity can be determined for each sampling site, currently no context exists for interpreting the condition of estuaries from fish diversity numbers because there are no criteria or thresholds for relating fish diversity estimates to estuarine condition.
- Fish populations are highly mobile, so caution must be used in interpreting low diversity estimates for measurements observed at any individual site may not be representative of the condition of the estuary.

Data Source

The data source for this indicator was the *Mid-Atlantic Integrated Assessment, MAIA-Estuaries, 1997-1998 Summary Report,* U.S. Environmental Protection Agency, May 2003. (See Appendix B, page B-46, for more information.)

Exhibit 5-36: Fish diversity in mid-Atlantic bays, 1997-1998



Coverage: Mid-Atlantic bays (Delaware, Maryland, New Jersey, Virginia).

Source: EPA, Office of Research and Development, Atlantic Ecology Division. *Mid-Atlantic Integrated Assessment, MAIA - Estuaries 1997-98, Summary Report.* May 2003.

Indicator Submerged aquatic vegetation - Category 2

Many estuarine systems contain submerged aquatic vegetation (SAV), which provides habitat and refugia for fish and invertebrates, helps protect shorelines from erosion, contributes to sediment accretion, and provides food for aquatic organisms. The vegetation also stabilizes shifting sediments and adds oxygen to the water. SAV is sensitive to pollution and shading by turbid water.

In the mid-Atlantic region, Mid-Atlantic Integrated Assessment (MAIA) field crews noted the presence or absence of SAV at their sampling stations as an ancillary measurement, but no attempt was made to estimate the extent of SAV. For the Chesapeake Bay, however, SAV extent is an ecological endpoint, and restoration of SAV is one of the goals of the Chesapeake Bay Program (Batiuk, et al., 2000).

What the Data Show

Scientists estimated that historically there were about 600,000 acres of SAV in the Chesapeake Bay. A 1978 aerial survey estimated that this SAV acreage had decreased to 41,000 acres, but total acreage had increased to over 69,000 acres by 2000 (Moore, et al., 2000). Extent measures are not currently available for the rest of the nation's estuarine systems.

Indicator Gaps and Limitations

The limitations of this indicator include the following:

- SAV estimates have been analyzed and reported only for the mid-Atlantic estuaries but not for the entire U.S.
- These SAV estimates are for presence/absence only and do not indicate the density or abundance of the vegetation. More quantitative approaches using remote sensing are being used, but this information is not currently available for the entire U.S. coastline.

Data Source

The data sources for these indicators were *Chesapeake Bay Submerged Aquatic Vegetation Water Quality and Habitat-Based Requirements and Restoration Targets: A Second Technical Synthesis*, U.S. Environmental Protection Agency, Chesapeake Bay Program, 2000; and *Mid-Atlantic Integrated Assessment, MAIA-Estuaries, 1997-1998 Summary Report*, U.S. Environmental Protection Agency, May 2003. (See Appendix B, page B-47, for more information.)

Indicator Fish abnormalities - Category 2

External abnormalities in fish can include lumps, growths, ulcers, fin rot, gill erosion, and gill discoloration. The cause of an abnormality is not always chemical contamination—it could also result from an injury or disease. A high incidence of such conditions could, however, indicate an environmental problem.

What the Data Show

The EPA EMAP Estuaries Program examined more than 100,000 fish from estuaries in the Virginian, Carolinian, Lousianian, and West Indian Province estuaries for evidence of disease, parasites, tumors and lesions on the skin, malformations of the eyes, gill abnormalities, and skeletal curvatures. Of all the fish examined, only 0.5 percent (454 fish) had external abnormalities (EPA, ORD, OW, September 2001). Of the fish examined, bottom-feeding fish had the highest incidence of disease, but this incidence was still low. There is no criterion for what constitutes a high or low number of fish abnormalities.

Indicator Gaps and Limitations

The limitations of this indicator include the following:

- Fish abnormality estimates are not available nationally for U.S. estuaries.
- Fish abnormalities can result from both natural causes such as injury and from chemical contamination, and the cause cannot be readily assessed.

Data Source

The data source for this indicator was *National Coastal Condition Report*, U.S. Environmental Protection Agency, September 2001, using data from the Environmental Monitoring and Assessment Program, Estuaries Program. (See Appendix B, page B-47, for more information.)

Indicator Unusual marine mortalities - Category 2

Unusual marine mortalities are characterized by an abnormal number of dead animals in locations or at times of the year that are not typical for that species. For animals such as turtles, whales, dolphins, seals, sea lions, or similar vertebrates, where small numbers of deaths can be significant, this indicator reports the actual number of dead animals. For other more abundant animals such as fish, sea birds, and shellfish, the number of mortality events is recorded. The cause of these unusual events might include infectious disease, toxic algae, pollutants, or natural events.

What the Data Show

More than 2,500 California sea lions were involved in unusual marine mortalities in 1992, which is more than 10 times the number of seals, sea lions, sea otters, or manatees lost in similar events since 1992 (The Heinz Center, 2002) (Exhibit 5-37). The next two largest events were the deaths of 150 manatees off the Florida coast in 1996 and the deaths of 185 California sea lions in 1997 (The Heinz Center, 2002). No causes for these events were cited in the Heinz report (The Heinz Center, 2002).

Indicator Gaps and Limitations

The limitations of this indicator include the following:

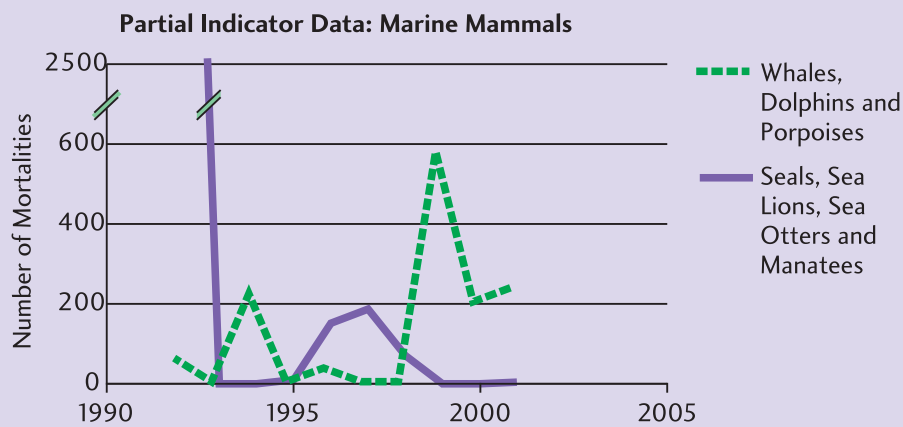
- This indicator represents only unusual events; it does not represent all observed mortalities of marine organisms.
- Criteria or thresholds do not exist for assessing the importance of unusual mortalities.
- It is not possible to determine if the event was caused by natural phenomena such as El Nino or was the result of anthropogenic influences.
- The data are not available on a national basis.

Data Source

The data source for this indicator was *The State of the Nation's Ecosystems,* The Heinz Center, 2002, using data from the U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries, Office of Protected Resources, Marine Mammal Health, Stranding Response Program, *CRC Handbook of Marine Mammal Medicine: Health, Disease, and Rehabilitation, 2nd edition* (Dierauf and Gulland, eds., 2001). (See Appendix B, page B-47, for more information.)

Exhibit 5-37: Unusual marine mortalities, 1992-2001

Data Not Adequate for National Reporting on Sea Turtles



Coverage: all U.S. waters.

Source: The Heinz Center. *The State of the Nation's Ecosystems.* 2002.
Data from the National Marine Fisheries Service and Dierauf and Gulland (2001).

Summary: The Ecological Condition of Coasts and Oceans

Coasts and oceans are subject to the same pressures as fresh waters, especially because they represent the endpoint for most fresh water drainage networks. Problems are exacerbated by the hydrology of estuaries, which tends to create conditions ideal for concentration of pollutants entering from upstream.

Landscape condition

The extent of this resource has been described by EPA and NOAA, and the landscape composition of much of the nation's coastline is known, providing a baseline against which to monitor future changes. As an example, 400,000 of 5,000,000 acres of coastal wetland were lost since the mid-1950s, although the loss rate declined in the 1990s (The Heinz Center, 2002). The baseline information is inadequate, however, for coral reefs, shellfish beds, and SAV, although a survey in Chesapeake Bay indicates that the acreage of SAV there increased from 41,000 to 69,000 acres since 1978 (Moore, et al., 2000). The estuarine landscape structure and pattern, and their contribution to ecological condition, remain inadequately measured or understood.

Biotic condition

The National Coastal Assessment, a joint federal and state interagency national monitoring program implemented to assess the ecological condition of the nation's estuaries, has developed regional data on several biotic condition indicators, including fish, benthic communities, and SAV. The program is also monitoring abnormalities and tissue contaminants. Results from three regions (Northeast, Southeast, and Gulf) indicate that, on average, 44 percent of the bottom community was in fair or poor condition, but this number varies among regions. Chlorophyll concentrations, which reflect the amount of phytoplankton growing in the water column, were over the recommended limit of 15 ppm (to protect SAV beds) over one-third of the estuarine area in the mid-Atlantic states. No similar estimates are yet available nationwide. Of more than 100,000 fish in random trawls from Maine to Texas, less than 0.5 percent showed visible evidence of disease, parasites, tumors or lesions of the skin, malformation of the eyes or gills, or skeletal curvature. Fish tissue contamination (other than non-toxic arsenic) was found in about 4 percent of fish.

Chemical and physical characteristics

A number of physical and chemical indicators are being monitored in estuarine systems to help diagnose and interpret biotic condition information. Data are available only for estuaries on the Atlantic or Gulf coasts, but 18 percent of mid-Atlantic estuaries were judged to have high nitrogen concentrations (which can lead to harmful algal blooms), and 12 percent had high concentrations of phosphorus. Twenty percent of Atlantic and Gulf estuaries had low dissolved oxygen concentrations (<5 ppm). On average, 75 percent of the sediments had elevated pesticide concentrations, and 40 percent had elevated concentrations of heavy metals, again with significant variation from region to region. Ten percent of the sediments showed a positive response to toxicity tests using a marine amphipod. Only 4 percent of the estuaries had poor light penetration.

There were no Category 1 or 2 indicators of *ecological processes, hydrology and geomorphology,* or *natural disturbance regimes* available for this report. The dearth of indicators for ecological processes is likely due, in part, to the fact that these indicators typically require repeated visits over several days, which makes systematic sampling in estuaries time-consuming and expensive. Procedures using remote sensing to assess ecological processes are being developed, but these are not ready for national or regional implementation. Hydrologic indicators may be similar to those for fresh water systems, but are complicated by the complex flows caused by tides and other phenomena in estuaries. An indicator of sea level change also may be useful. Storms, hurricanes, and similar disturbances are monitored globally, nationally, regionally, and locally, but this information has not been developed in the form of an indicator.

Information on disturbance regimes could also be used to partition observed estuarine system responses into portions attributable to natural versus anthropogenic disturbances.

5.8 What Is the Ecological Condition of the Entire Nation?

The previous sections asked questions about the ecological condition of forests, coasts and oceans, fresh water ecosystems, urban and suburban areas, farmlands, and grasslands and shrublands nationally. Because ecosystems are hierarchical (O'Neill, et al., 1986) some important questions about ecological condition cannot be answered in terms of these land cover classes. Examples of large-scale issues include the following:

- The relative distribution of forests, grasslands, farmlands, and urban/suburban areas across the entire nation.
- Neotropical migratory birds and other species do not depend on one ecosystem type, but many, often spread over large regions.
- The condition of forest streams, and of other low-order streams across regions, was considered in Section 5.6, but processes in very large watersheds (e.g., the Mississippi or Columbia River basins) reflect the sum total of contributions from many ecosystem types.
- Typically, large systems are slower to change and to respond to management actions (O'Neill, et al., 1986; Messer, 1992). Global climate change and changes in stratospheric ozone are examples of stressors of this type (Rosswall, et al., 1988).

Because EPA's regulatory programs, both alone and in combination, typically impact many kinds of ecosystems, such large-scale questions are an important part of tracking the overall effectiveness of these programs in protecting the entire nation.

Exhibit 5-38 shows the indicators for the entire nation used in this report. All seven of the indicators are taken from the core national indicators in *The State of the Nation's Ecosystems* (The Heinz Center, 2002). There are indicators for four of the six essential ecological attributes with at least regional data, but no indicators on hydrology and geomorphology or natural disturbance regimes with data available on a national or regional level (The Heinz Center, 2002).

Exhibit 5-38: Indicators covering the entire nation

Essential Ecological Attribute	Indicators	Category 1	Category 2	Source
Landscape Condition				
Extent	Ecosystem extent	■		USDA, DOI, DOC
Landscape Composition				
Landscape Pattern/Structure				
Biotic Condition				
Ecosystems and Communities	At-risk native species		■	NatureServe
Species and Populations	Bird Community Index		■	EPA
Organism Condition				
Ecological Processes				
Energy Flow	Terrestrial Plant Growth Index	■		DOI, DOC
Material Flow	Movement of nitrogen	■		DOI
Chemical and Physical Characteristics				
Nutrient Concentrations				
Other Chemical Parameters				
Trace Organic and Inorganic Chemicals	Chemical contamination		■	DOI, EPA
Physical Parameters				
Hydrology and Geomorphology				
Surface and Ground Water Flows				
Dynamic Structural Conditions				
Sediment and Material Transport				
Natural Disturbance Regimes				
Frequency				
Extent				
Duration				

Indicator Ecosystem extent - Category 2

Extent provides basic information on how much of an ecosystem exists, where it is, and whether it is changing over time. Changes in the extent of various cover types in the U.S. have been driven primarily by human land and water uses over the past 400 years. The total amount and relative distribution of land-cover types at the regional and national level are important, because ultimately they affect many of the ecological attributes such as biodiversity. For example, not only do forest species depend on forests, but many forest species also depend on adjacent wetlands or grasslands.

What the Data Show

Estimates show that before European settlement, the U.S. had 1 billion acres of forests (USDA, FS, 2002), 900 to 1,000 million acres of grasslands and shrublands (Klopatek, et al., 1979) and 221 million acres of wetlands (Dahl, 2000). Today, the U.S. has 749 million acres of forests (USDA, FS, 2002), 861 million acres of grasslands and shrublands (The Heinz Center, 2002), and 106 million acres of wetlands (Dahl, 2000). About 530 million acres of croplands (USDA, NRCS, 2000) and 90 million acres of urban and suburban land uses (USDA, NRCS, 2001) have been added.

The acreage of forest and fresh water wetlands have each declined by about 10 million acres in the decades since the 1950s; the acreage of croplands has fluctuated, but it is currently about 35 million acres less than in the 1950s; and urban areas have grown by 40 million acres during the same period (The Heinz Center, 2002) (Exhibit 5-39).

Indicator Gaps and Limitations

According to The Heinz Center (2002), the National Land Cover Database (NLCD) produced different estimates of area for forests and farmlands from those mentioned above, because of differences in the definitions of these systems in the Forest Inventory and Analysis (FIA) and the USDA Economic Research Service (ERS). In addition, current indicators of extent do not provide information about fragmentation and landscape patterns.

Data Sources

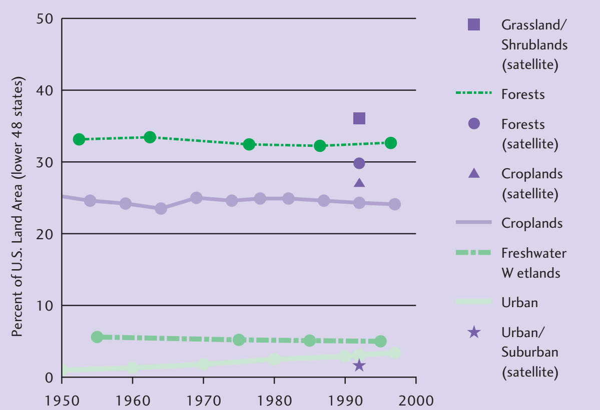
The data sources for these indicators were Forest Inventory and Analysis, U.S. Department of Agriculture (1979-1995); National Land Cover Database, Multi-Resolution Land Characteristics Consortium (1990s); National Wetlands Inventory, U.S. Fish and Wildlife Service (1970-2000); and Economic Research Service, U.S. Department of Agriculture (1982-1997). (See Appendix B, page B-48, for more information.)

Exhibit 5-39: Change in ecosystem extent, long-term and recent trends, 1950s-1990s

Data Not Adequate for National Reporting on Extent of brackish coastal waters

Partial Indicator Data: Long-term Changes for For Forests, Croplands, Grasslands/Shrublands, Urban/Suburban

Partial Indicator Data: Recent Trends for Forests, Croplands, Grasslands/Shrublands, Urban/Suburban, Freshwater Wetlands



Coverage: lower 48 states.

Note: Because these estimates are from different sources, they do not sum to 100% of U.S. land area. Approximately 5% of lands are not accounted for by these data sources. They include some wetlands, some non-suburban developed areas, disturbed areas such as mines and quarries and the like. In addition, freshwater wetlands currently occupy approximately 5% of the area of the lower 48 states, a reduction of about 50% since presettlement times. Because they are found within forests, grasslands, and shrublands, or croplands, freshwater wetlands from those ecosystems are shown as aggregated data on the graph. Finally, the "urban" trend line in this graph is based on a different definition from the one in this report and is presented here to illustrate general trends. The definition used in this report was used to generate the "urban/suburban (satellite)" area estimate.

Source: The Heinz Center. *The State of the Nation's Ecosystems.* 2002.
Data from the USDA Forest Service (forests, current area, recent trends), USDA Economic Research Service (croplands trends, urban area trends), Multi-Resolution Land Characterization Consortium (MRLC; all satelite data, including current estimate of grass/shrub and urban/suburban area in top graph). Presettlement estimates are from Klopatek et al. 1979.

Indicator **At-risk native species - Category 2**

Scientists are engaged in considerable discussion about the importance of rare and at-risk species for the sustainability of ecosystems (e.g., Grime, 1997; Hodgson, et al., 1998; Naeem, et al., 1999; Tilman and Downing, 1994; Wardle, et al., 2000). There are at least 200,000 native plant, animal, and microbial species in the U.S., but according to The Heinz Center (2002), "little is known about the status and distribution of most of these." This indicator represents what is known about 22 species groups, including 16,000 plant species and 6,000 animal species. It includes all higher plants; all terrestrial and fresh water vertebrates (i.e., mammals, birds, reptiles, amphibians, and fish); select invertebrate groups, including fresh water mussels and snails, crayfishes, butterflies and skippers; and about 2,000 species of grasshoppers, moths, beetles, and other invertebrates (The Heinz Center, 2002). The Heinz Center believes that this indicator is a powerful—yet manageable—snapshot of the condition of U.S. species. No data are available for marine species, which led The Heinz Center to rank this as an indicator equivalent to a Category 2. Special groupings of these species have been used as indicators in specific ecosystem categories. This indicator includes all of them, but The Heinz Center has not analyzed species dependent on large or multiple ecosystems.

What the Data Show

One-third of species native species are at risk, and 1 percent of plant and 3 percent of animal species might already be extinct (The Heinz Center, 2002) (Exhibit 5-40). Approximately 19 percent of native animal species and 15 percent of native plant species are ranked as imperiled or critically imperiled. There are large differences among plant and animal groups and among regions. For example, the percentage of at-risk fresh water species such as mussels and crayfish is much higher than that for birds or mammals, and more at-risk species are found in California, Hawaii, the southern Appalachians, and Florida than elsewhere (Stein, 2002).

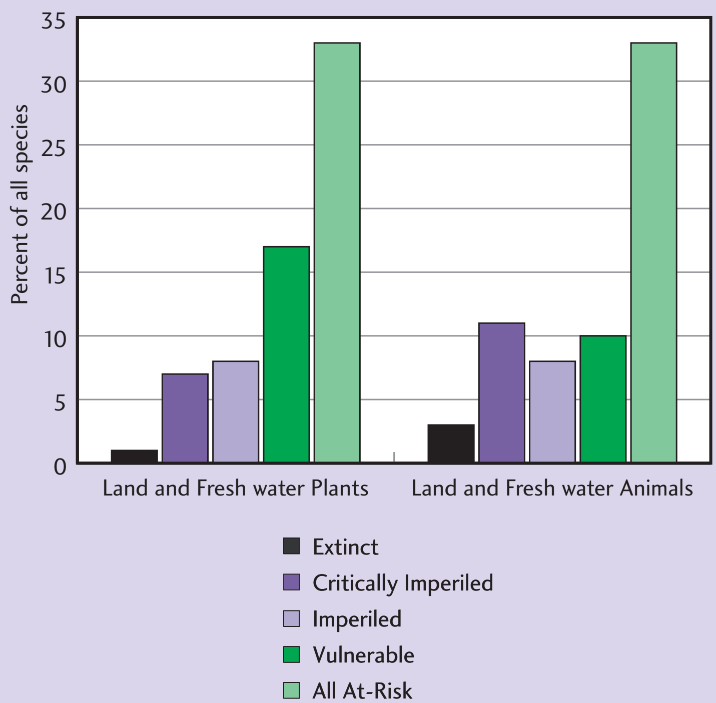
Indicator Gaps and Limitations

The data are from a census approach that focuses on the location and distribution of at-risk species. Therefore, distinguishing trends in the indicator is difficult.

Data Source

The data for this indicator was *The State of the Nation's Ecosystems,* The Heinz Center, 2002, using data from the NatureServe Explorer database. (See Appendix B, page B-48, for more information.)

Exhibit 5-40: At-risk land and fresh water plant and animal native species, 2000



Coverage: all 50 states.

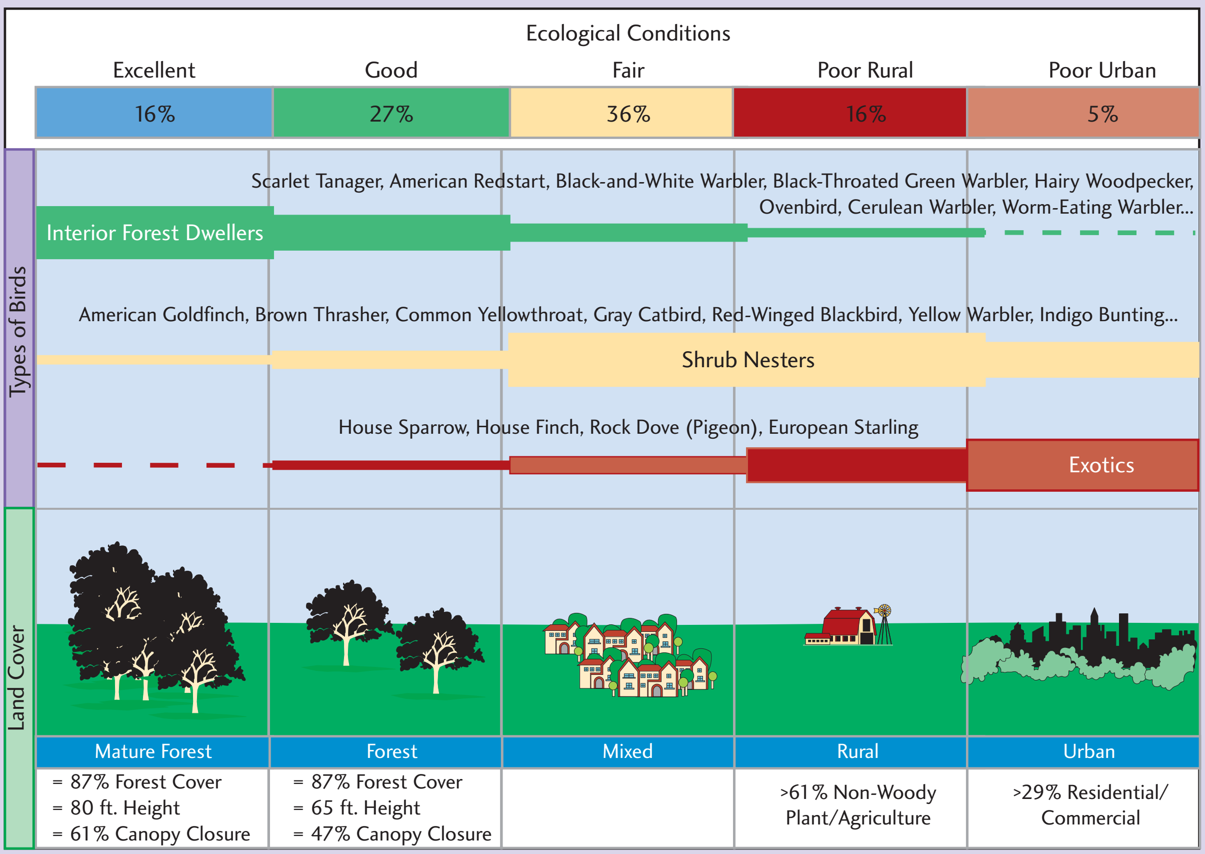
Source: The Heinz Center. *The State of the Nation's Ecosystems.* 2002. Data from NatureServe and its Natural Heritage member programs.

Indicator Bird Community Index - Category 2

The types of birds observed in an area have been shown to serve as an indicator of the overall characteristics of the landscape. Species vary in their sensitivity to physical, chemical, and biological threats, and different species require different habitats for food, shelter, and reproduction. Some species need extensive areas of interior forest, others prefer the edges between different types of land cover or mixed areas, and still others prefer disturbed or highly managed areas. Consequently, the composition of the bird community reflects the overall mix, pattern, and condition of the mosaic of forest, agriculture, grasslands and shrublands, wetlands, streams, and urban/suburban areas that makes up most of the U.S. landscape.

The Bird Community Index (BCI) was developed by O'Connell, et al. (1998, 2000) for songbirds in the mid-Atlantic states. The index was developed based on data collected at 34 reference sites, with bird species classified into 16 functional groups according to the degree to which they specialized in using the native flora and fauna in an area (high BCI scores) versus being generalists and exotic or invasive species (low BCI scores). The BCI then was applied to a probability sample of bird data from 126 sites across the Mid-Atlantic Highlands.

Exhibit 5-41: Bird species as characteristics of landscape composition and pattern as an indicator of landscape condition, 1995-1996



Coverage: Mid-Atlantic Highlands (Maryland, Pennsylvania, Virginia, West Virginia).

Source : EPA, Office of Research and Development. *Birds Indicate Ecological Condition of the Mid-Atlantic Highlands.* June 2000.

Indicator Bird Community Index - Category 2 (continued)

What the Data Show

Good-to-excellent BCI scores (diverse communities of birds characterized by many specialists and native species) were associated with at least 87 percent forest cover and a minimum of 47 percent canopy closure. Poor BCI scores (low diversity communities characterized by generalists and exotic species) were associated with either rural agricultural or urban areas where almost 30 percent of the landscape was in residential or commercial land use.

The BCI was calibrated across a range of landscape conditions from least disturbed to significantly degraded. Based on this calibration, 43 percent of the Mid-Atlantic Highlands was estimated to be in good to "excellent" condition (in other words, containing large tracts of interior forest), 36 percent was estimated to be in "fair" condition, and 21 percent (5 percent urban and 16 percent rural) was estimated to be in "poor" condition (Exhibit 5-41). Forested sites in good and excellent condition supported different bird communities and ground-level vegetation attributes, but could not be separated by land cover composition alone. As the proportion of the landscape in forested areas decreased or the proportion of canopy closure decreased, so did the BCI scores (O'Connell, et al., 1998, 2000).

Indicator Gaps and Limitations

The limitations of this indicator include the following:

- This indicator depends on a value judgement common among ecologists that communities associated with the native vegetation of a region are "better" than exotic, generalist species associated with human modification of the environment.
- The BCI has been calibrated and assessed only for the Mid-Atlantic Highlands, and may not apply to areas where shoreline birds or migratory waterfowl are a larger component of the bird community.
- The BCI relates primarily to land cover estimates, and does not explicitly include the condition of any particular land cover type.

Data Source

The data sources for this indicator were *A Bird Community Index of Biotic Integrity for the Mid-Atlantic Highlands,* O'Connell, et al., 1998; and *Bird Guilds as Indicators of Ecological Condition in the Central Applachians,* O'Connell, et al., 2000, using data from U.S. Environmental Protection Agency Mid-Atlantic Highlands Program and the National Land Cover Database. (See Appendix B, page B-48, for more information.)

Indicator Terrestrial Plant Growth Index - Category I

Both the National Research Council and Science Advisory Board reports suggest that primary productivity (the amount of solar energy captured by plants through photosynthesis) is a key indicator of ecosystem function (NRC, 2000; SAB, 2002). Generally, ecosystems will maximize their primary productivity through adaptation (Odum, 1971), so primary productivity can increase under favorable conditions (e.g., increased nutrients or rainfall) or decrease under unfavorable conditions (e.g., plant stress caused by toxic substances or disease). Changes in primary productivity can result in changes in the way ecosystems function, in the yield of crops or timber, or in the animal species that live in the ecosystems.

Gross primary productivity is related to the standing crop of the photosynthetic pigment chlorophyll and can be thought of in simple terms as plant growth. The Terrestrial Plant Growth Index indicator is based on the Normalized Difference Vegetation Index (NDVI), which measures the amount of chlorophyll, using satellite data (The Heinz Center, 2002). While the standing crop of chlorophyll is not identical to primary productivity, EPAs Science Advisory Board (EPA, SAB, 2002) lists it as an example of an indicator under the ecological processes EEA.

What the Data Show

No overall trend in plant growth is observed for the 11-year period from 1989 through 2000, for any land cover type or any region of the U.S., although year-to-year measurements can fluctuate by up to 40 percent of the 11-year average (The Heinz Center, 2002) (Exhibit 5-42). Over a sufficiently long period, regional trends in NDVI could be an important indicator of increasing or decreasing plant growth resulting from changing climate, UV-B exposure, air pollution, or other stressors.

Indicator Gaps and Limitations

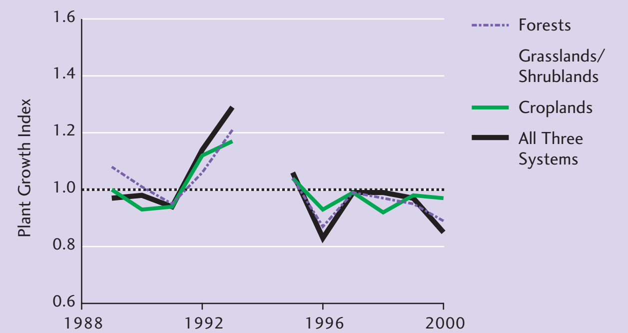
There were no calculations for phytoplankton or submerged vegetation growth in fresh water or coastal systems.

Data Source

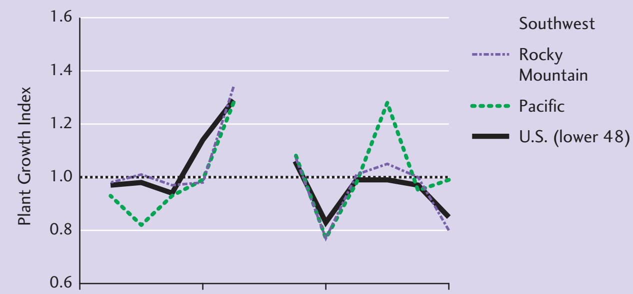
The data source for this indicator was *The State of the Nation's Ecosystems*, The Heinz Center, 2002, using data on visible and near-infrared wavelengths collected by the National Oceanic and Atmospheric Administration's Advanced Very High Resolution Radiometer and converted into a Normalized Difference Vegetation Index (Reed and Young, 1997). (See Appendix B, page B-49, for more information.)

Exhibit 5-42: Plant Growth Index, 1989-2000

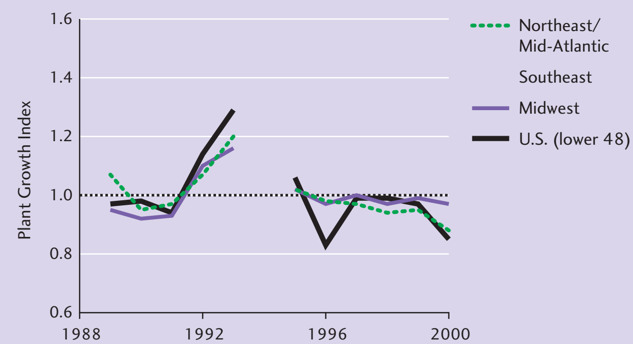
Terrestrial Plant Growth Index for lower 48 states



Plant Growth Index: southwest, rocky mountain, pacific regions



Plant Growth Index: northeast, southeast, midwest regions



Coverage: Lower 48 states.

Note: Because of satellite problems, no data are available for 1994.

Source: The Heinz Center. *The State of the Nation's Ecosystems*. 2002.
Data from the U.S. Geological Survey; Multi-Resolution Land Characterization Consortium.

Indicator

Movement of nitrogen - Category I

Nitrogen is a critical nutrient for plants, and "leakage" of nitrogen from watersheds can signal a decline in ecosystem function (Vitousek, et al., 2002). It also may signal the failure of watershed management efforts to control point, non-point, and atmospheric sources of nitrogen pollutants, and the resulting nitrogen may have "cascading" harmful effects as it moves downstream to coastal ecosystems (Galloway and Cowling, 2002). Nitrate concentration in streams has served as an indicator of chemical condition in the other ecosystems in this section. This indicator, however, deals with nitrogen export from large watersheds, and is an indicator of ecosystem function.

What the Data Show

Nitrate export from the Mississippi River has been monitored since the mid-1950s and from the Susquehanna, St. Lawrence, and Columbia Rivers since the 1970s, and is reported in The State of the Nation's Ecosystems in tons per year. The load in the Mississippi River has fluctuated from year to year, but it has increased from approximately 250,000 tons per year in the early 1960s to approximately 1,000,000 tons per year during the 1980s and 1990s (The Heinz Center, 2002) (Exhibit 5-43). The Mississippi River drains the agricultural "breadbasket" of the nation and contains a large percentage of the growing population, so the increases likely reflect failure to control nitrogen pollution, rather than a breakdown in ecosystem function (e.g., Rabalais and Turner, 2001). Nitrate loads in the other three rivers have fluctuated around 50,000 tons per year since the 1970s, although the Columbia River spiked to 100,000 tons per year in the late 1990s.

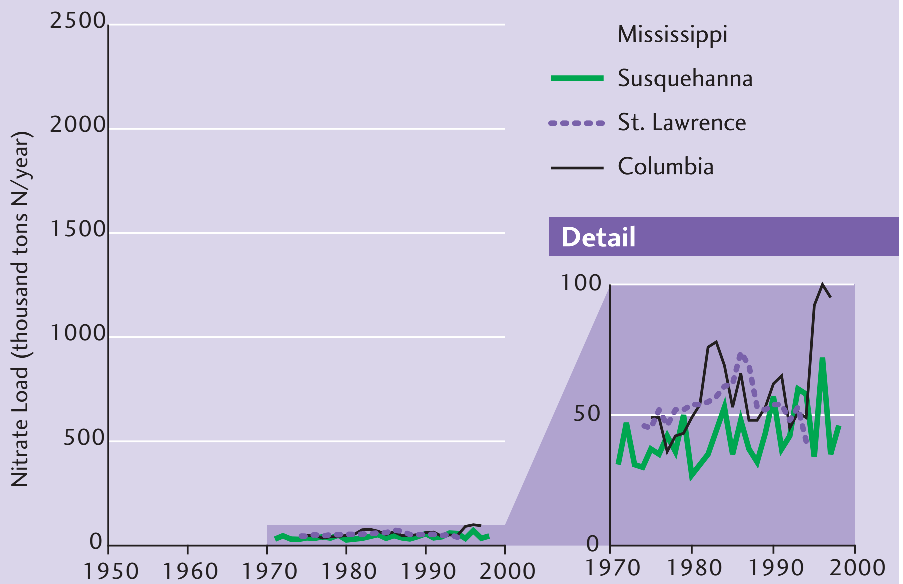
Indicator Gaps and Limitations

The indicator does not include data from numerous coastal watersheds whose human populations are rapidly increasing and are therefore estimated to have high nitrogen loss rates (e.g., Valigura, et al., 2000). It also does not include other forms of nitrogen besides nitrate, which may constitute a substantial portion of the nitrogen load.

Data Source

The data source for this indicator was *The State of the Nation's Ecosystems,* The Heinz Center, 2002, using data collected by the U.S. Geological Survey, National Stream Quality Accounting Network and National Water Quality Assessment Program, and by the U.S. Army Corps of Engineers. (See Appendix B, page B-49, for more information.)

Exhibit 5-43: Nitrate load carried by major rivers, 1970-1999



Coverage: selected major rivers.

Source: The Heinz Center. *The State of the Nation's Ecosystems.* 2002.
Data from the U.S. Geological Survey's National Stream Quality Network (NASQAN), National Water Quality Assessment (NAWQA), and Federal-State Cooperative Program.

Indicator Chemical contamination - Category 2

This indicator has been discussed for the individual ecosystems, but here it is reported for all media, regardless of land-cover type. The following is a summary of the key findings; the Heinz report (2002) should be consulted for further details.

What the Data Show

Three-fourths of all streams in the National Water Quality Assessment (NAWQA) network had one or more contaminants that exceeded guidelines for the protection of aquatic life, and one-fourth had four or more contaminants over those levels. One-fourth of ground water wells sampled had one or more contaminants above human health standards. One-half of all streams had one or more contaminants in sediments that exceeded wildlife protection guidelines (usually more stringent than criteria to protect human health). One-half of all fish tested had one or more contaminants that exceeded wildlife protection guidelines. Approximately 60 percent of estuarine sediments tested had concentrations of contaminants expected to lead to “possible effects” in aquatic life, and 2 percent had concentrations exceeding levels expected to have “likely effects.”

Indicator Gaps and Limitations

The limitations of this indicator include the following:

- While these data represent a comparison of a standard to the respective contaminant concentration, they do not represent assessments of risk posed to humans or ecosystems.
- Different standards also reflect different levels of protection, so these data should be interpreted cautiously.
- Media contamination, such as water or sediment contamination, does not necessarily indicate exposure to the contaminant for either humans or other biological populations.

Data Source

The data source for this indicator was *The State of the Nation's Ecosystems,* The Heinz Center, 2002, using data from the National Water Quality Assessment Program and the Environmental Monitoring and Assessment Program, Estuaries Program. (See Appendix B, page B-50, for more information.)

Summary: The Ecological Condition of the Entire Nation

The idea of monitoring indicators that could include the entire nation, irrespective of the type of land cover, has not been a main topic of ecological monitoring. The main idea is that pressures acting over large areas may have effects that transcend a land cover type, or may depend on the interaction of land cover types. The issue of scale has not been well-articulated with respect to these indicators (issues of national scope may not operate at national scales). This is an area of attention for future reports.

Landscape condition

The National Land Cover Database (NLCD) now provides a consistent national picture of the extent of the various ecosystem types at 30 meter (about 100 foot) resolution (Vogelmann, et al., 2001). A consortium of federal agencies performs the interpretation of the satellite data necessary for development of the NLCD. Much of the data in this indicator come from the Forest Inventory and Analysis (FIA) or the National Resources Inventory (NRI), which allows trends to be estimated during periods prior to the first NLCD coverage. Unfortunately, these data are not comparable to the NLCD, because of differences in the definitions of the land cover categories (see Chapter 3, Better Protected Land).

Biotic condition

With respect to the at-risk native species indicator, the NatureServe database is an invaluable resource for identifying these species. Because the resulting data are developed without an underlying statistical design, however, it will be difficult to determine whether future trends are the result of more thorough field work and reporting by researchers and resource managers, or actual trends in the number of at-risk species. An effort has begun to identify all species in the Smoky Mountain National Park (Kaiser, 1999), and an international effort, called Species 2000, is being developed by a multinational project team associated with the United Nations (U.N.) Convention of Biological Diversity. Recent research expanding the bird diversity index to the entire mid-Atlantic region shows that it has promise as a national indicator (O'Connell, et al., 2002). Analysis of the biological data from the first 20 National Water Quality Assessment (NAWQA) study units, and similar analyses of Environmental Monitoring and Assessment Program (EMAP) data from the national estuaries and streams in the West and Midwest, should shed some light on the feasibility of a national indicator for estuarine and stream benthic communities. Because the plankton communities of lakes do not exhibit a high degree of biogeographical variation (independent of natural factors such as hardness or the presence of organic color), a national plankton index would seem feasible if the necessary data were collected.

Ecological processes

The *Terrestrial Plant Growth Index* is probably the best example of the indicator of primary productivity called for by both the NRC (2000) and SAB (2002). Comparable data exist on trends for a decade, with census coverage (at the resolution of the AVHRR sensor) for the conterminous U.S. Examination of the trends data for this indicator in The Heinz Center (2002) report shows large (±40 percent) excursions from the 11-year average in the Southwest, and ±20 percent excursions in the Pacific region. The amount of time necessary to separate changes caused by air pollutants (e.g., ozone, nitrogen deposition, carbon dioxide) from those caused by natural climatic factors and insect and disease outbreaks is unknown.

The Movement of Nitrogen indicator certainly captures trends in this important nutrient in the nation's largest river basins. The indicator would be improved if it included total nitrogen, including an accurate estimate of nitrogen carried in the bed load of sediments as it moves into coastal waters, and if it were extended to the many smaller coastal watersheds that are experiencing large increases in population. An indicator of sediment runoff potential would be a useful large-ecosystem indicator if it were extended to non-farmland ecosystems (see Chapter 3, Better Protected Land).

Chemical and physical characteristics

The *Chemical Contamination* indicator raises a serious question about how representative the streams in the NAWQA study units are. There were 119 NAWQA sites with surface water monitoring data, located in 20 geographically well-dispersed watersheds across the U.S. Eventually, NAWQA plans to expand to 60 such units, and presumably all will include water sampling. On a national basis, this might be an adequate number to represent the range of factors affecting ecological condition of the streams and watersheds. The number of streams characterizing forest, farmland, or urban/suburban watersheds seems too small, however, given the very wide range of nutrient and contaminant concentrations presented in the Heinz report.

More important, however, is whether the streams sampled are representative of the range of streams in the entire nation. The ecological condition of fresh waters (and their watersheds) reflects the sum total of natural factors (including disturbances), conscious and unconscious decisions about land-use management (e.g., what crops to grow, whether and when to cut timber, urban planning and zoning), and the presence and control of pollutants. A particular stream might be representative of a watershed with respect to geomorphology and hydrology, and even land use (e.g., corn or tree farming, urban or suburban). But resource management decisions and the presence or control of pollutants are particular to a specific watershed, and so the streams must be chosen to be representative of the full range of possibilities, and of their relative frequencies. With respect to pollution control, assuming that the full set of environmental controls are working as envisioned by EPA is particularly risky. In fact, this risk is one of the primary reasons for monitoring progress toward national goals under GPRA; to determine if the programs, as implemented and enforced by the states are really protecting and restoring the biological integrity of fresh waters. In this context, identifying representative streams or watersheds is not as reasonable as identifying representative samples of streams or watersheds. Until the NAWQA streams can be compared to a statistically representative sample of streams, great care must be taken in assuming that the data accurately reflect the national condition of fresh waters and watersheds.

There were no Category 1 or 2 indicators available for this report for *hydrology and geomorphology* or *natural disturbance regimes,* but developing them does not seem to be a particularly daunting challenge, given the widely available data on geology, flow, and paleological methods to indicate the regional occurrence of climatic events and fire.

5.9 Challenges and Data Gaps

The availability of indicators across ecosystem types is summarized in Exhibit 5-44. Indicators that currently can provide national information on ecological condition are available for only 14 of the possible 126 indicator categories in the framework. More than half of the Category 1 indicators provide information only on ecosystem extent and landscape composition, with a few exceptions:

- The Forest Inventory and Analysis (FIA) and Forest Health Monitoring (FHM) programs together have achieved representative national coverage for both the present status and historical trends in the occurrence of fire, insect damage, and disease for forests.
- Satellite data provide continent-wide status and trends in the Normalized Difference Vegetation Index (NDVI), which serves as a surrogate for primary productivity, or the amount of energy available at the base of the ecosystems.[17]
- Historical hydrology data were analyzed for The Heinz Center report to determine trends in high and low-flows for more than 800 streams with no specified land cover and more than 500 forest streams across the U.S., and the number and duration of dry periods were calculated for 152 streams in grasslands, shrublands, and dry areas. These analyses could presumably have been performed for urban/suburban, agricultural, and very large watersheds, but they have not been performed to date.
- The current status and historical trends in the potential for sediment transport from farmland can be calculated from existing data (though not the amount of sediment actually lost).

For the rest of the essential ecological attributes, only partial data exist, at best (e.g., regional data or data for only part of the resource), for one or more indicators. For more than one-half of the major indicator categories in the seven ecosystem types, not even one indicator was identified for this report. For many more, only one existed, though several would be necessary. This situation will improve slightly in the next year or two. A number of active research programs are collecting and analyzing relevant ecological condition data at the national or regional level, but the results had not yet met the criterion for peer review at the time this report was finalized. Two years from now, research on indicators from the FIA program, FHM program, the National Water Quality Assessment (NAWQA) program, and the Environmental Monitoring and Assessment Program (EMAP) Western Streams Pilot should provide new Category 2, and a few Category 1 indicators, primarily biotic condition and ecological process indicators. As of now, the gaps are substantial.

[17] There is some debate as to whether standing crop chlorophyll can really be a surrogate for primary productivity, so this might be more appropriate as an ecosystem condition indicator.

What the Available Indicators Reveal about Some Ecological Issues of Recent Concern to EPA

The introduction to this chapter identified three reasons to monitor ecological condition:

- To establish baselines against which to assess the current and future condition of ecosystems.
- To provide a warning that action may be required.
- To track the outcomes of policies and programs, and adapt them as necessary.

This section addresses the question of how well the available indicators of ecological condition, notwithstanding the gaps evident in Exhibit 5-44, serve these purposes for some ecological issues that have been of concern to EPA over the past decade. These do not reflect all such issues, or signify EPA's priorities, but simply typify a diverse set of challenges for national ecological monitoring:

- Forest dieback
- Vertebrate deformities
- Harmful algal blooms
- Eutrophication
- Loss of biodiversity
- Non-target organism effects from pesticides and herbicides
- Issues related to ozone, UV-B, mercury, acidic deposition, and persistent bioaccumulative toxics (PBTs)

For the first five issues listed above, biota were harmed before the cause was known. For the other two, a perceived risk exists, but the extent of actual harm or exposure is unknown. In either case, data on the extent or trends in ecological condition is needed to inform how research is targeted or regulatory programs adjusted. Identifying indicators of the appropriate essential ecological attribute also should help to identify some of the factors that might be contributing to the extent of and trends in harm to biota and ecosystem function (EPA, SAB, 2002).

Forest dieback

Forest dieback can be exacerbated, if not caused, by some combination of acid deposition, air pollution, UV-B radiation, disease, insects, and unusual climate events (USDA, FS, 2002). Currently, the forest indicators provide a baseline for the extent of poor tree condition in 37 states; soon, these indicators will provide a baseline and future trends for the conterminous U.S. NDVI data are available as a surrogate for primary productivity in forests. FIA program plots are being examined for indications of harm to ozone-sensitive species. Relevant soil data (exchangeable base cations) are being measured, even though that indicator cannot yet be reported. A UV-B monitoring network has been collecting data for less than 2 years, and the data are currently being evaluated. Data for ozone and acid deposition in high elevation forests remain poor, as do climate data. Most of these indicators are being monitored using a probability design, so continued FIA monitoring can provide a national baseline for assessing the extent and trends in forest dieback, and some of the EEAs that may contribute to it.

Vertebrate deformities

The ability of exogenous chemicals to interfere with normal endocrine functioning and related processes of an organism has raised increasing concerns for human health and the environment. Studies have reported that both synthetic and naturally occurring compounds interfere with normal endocrine function of invertebrates, fish, amphibians, reptiles, birds, and mammals causing effects such as birth defects, impaired fertility, masculinization of female organisms, feminization of male organisms, or organisms with both male and female reproductive organs. Two recent reports summarize available data from field and laboratory studies and provide an assessment of the state of the science (EPA, RAF, 1997; IPCS, 2002). The existing challenge is to further elucidate the cause-and-effect relationships for the observed adverse effects, determine which chemicals are of greatest concern, and the extent to which these chemicals negatively impact populations of fish and/or wildlife.

The only indicator identified in this chapter that tracks the extent or trends in animal deformities (irrespective of the cause) is a Category 2 indicator, Fish Deformities, collected by EMAP in coast and ocean ecosystems. Data are being collected on amphibian deformities by the USGS, using reports from a wide array of sources. A new national survey, the Amphibian Research and Monitoring Initiative, was established by USGS in 2000. However, it may be several years before USGS and EPA can detect national and/or regional trends from this initiative. Until there is a better understanding of which chemicals are of greatest concern, there is also some question about which chemi-

Exhibit 5-44: Distribution of available ecological condition indicators across the ecosystem types

Essential Ecological Attribute	Forests	Farmlands	Grasslands/ Shrublands	Urban/ Suburban	Fresh Waters	Coasts and Oceans	The Nation
Landscape Condition							
Extent of Ecological System/Habitat Types	1 1	1	1	1	1 1	1	1
Landscape Composition	2	1		2	2	2 2	
Landscape Pattern/Structure	2						
Biotic Condition							
Ecosystems and Communities	2		1 2		2 2 2 2 2	2 2 2	2
Species and Populations	2				2	2	2
Organism Condition	1 2 2				2	2 2	
Ecological processes							
Energy Flow							1
Material Flow	2						1
Chemical & Physical Characteristics							
Nutrient Concentrations	2	2 2		2 2	2 2	2 2	
Other Chemical Parameters	2 2				2	2 2	
Trace Organic /Inorganic Chemicals		2 2 2 2		1 2	2	2 2	2
Physical Parameters	2					2	
Hydrology and Geomorphology							
Surface and Ground Water Flows	1		1		1		
Dynamic Structural Conditions							
Sediment and Material Transport	2	2 2			2		
Natural Disturbance Regimes							
Frequency	2						
Extent							
Duration							

Note: Numbers correspond to indicator categories presented in this report.

cals to monitor in the fish and wildlife habitat. Additional information on chemicals will become available once EPA has fully implemented an Endocrine Disruptor Screening Program to test a chemical for its potential endocrine disruption activity.

Harmful algal blooms

Scientists have also been concerned about the condition of the nation's estuaries and in particular, about a perceived increase in harmful algal blooms (HABs); loss of submerged aquatic vegetation (SAV), which serves as habitat for fish; and sediment toxicity, which might limit the productivity of an important component of the estuarine food chain (Anderson and Garrison, 2000; Gallagher and Keay, 1998). EMAP, working with the states, has collected data on the condition of SAV, estuarine fish communities, estuarine benthic communities, sediment toxicity, and nutrient concentrations that should provide representative status and trends data for these indicators. The sampling design does not allow tracking of the frequency and extent of HABs or nutrient levels in estuaries, but USGS does monitor nutrient loads to coastal systems from four of the largest U.S. rivers. Continued monitoring of the estuaries is subject to state-by-state availability of funding.

Eutrophication

EPA has recently focused substantial attention on the listing by the states of their waters that do not meet their designated uses (usually expressed in terms of their ability to support aquatic life), and developing total maximum daily loads of pollutants that would allow the designated use to be achieved. Concern over eutrophication of lakes and reservoirs has prompted EPA to begin developing regional standards for the nutrients nitrogen and phosphorus. At present, there is no indicator monitoring suitable to track progress in reducing the number of eutrophic lakes and streams or the condition of the biotic communities in rivers and streams at the national or even regional level. Indicators monitored by the states are not comparable, the same waters are not necessarily sampled over time, and their representativeness is unknown and questionable. NAWQA uses comparable methods and intends to monitor the same streams over time, but the number of such streams in the various ecosystem types is too small to adequately represent all the factors that contribute to water quality at the national level. While the data are likely to be broadly representative of certain types of streams, they cannot be expanded to all streams with known statistical reliability. This fact is particularly important if the combination of factors affecting water quality in the study units (which depend on a variety of factors, including water quality management by the states, national patterns of air pollution and acid rain, geology and land use, and climate) is not statistically representative of these factors nationally. EMAP has demonstrated regional approaches to statistically representative sampling that include both biology and chemistry, but has not yet reported on relationships between them, nor is there any long-term commitment to repeating the pilot studies or expanding them to other regions. EPA is currently working with the states to rectify this situation, and some progress is reported in Chapter 2, Purer Water.

Loss of biodiversity

EPA is concerned generally about biodiversity, and this is one of the primary areas on which EPA comments in Environmental Impact Statements for significant projects involving federal funding under NEPA. The NatureServe indicator reported for many of the ecosystems is invaluable in indicating species at risk in the vicinity of such projects. Because the database is not based on a systematic survey of plots over time, however, it is not clear how to interpret data that are not reported. For example, the current data cannot distinguish naturally rare species from species whose numbers have been reduced. It is not clear how to determine whether future trends are the result of better (or less) field work or the actual status of the species in question. The answer likely depends on the species, but at this point the data seem less than ideal for national reporting.

Non-target organism effects from pesticides and herbicides

EPA is concerned about non-target organism effects from pesticides and herbicides. Pesticides and herbicides (including those incorporated into the genomes of crops) are registered for use by EPA such that their use in accordance with the registration is not expected to pose unnecessary risks to non-target organisms. Nonetheless, neither the models nor the compliance are likely to be perfect, so tracking any residues of such pesticides in non-target organisms would be useful, as would identifying any harm or mortality of organisms that might be caused by improper use of pesticides. There are Category 2 indicators for pesticide application and leaching pesticides in stream biota, and pesticides in sediment and fish tissue for fresh waters. There are no indicators in The Heinz Center report for pesticides in terrestrial organisms. Another indicator that might provide presumptive evidence of harm—animal die-off in fresh waters—is adequate for national reporting only for waterfowl.

Issues related to ozone, UV-B, mercury, acidic deposition, and persistent bioaccumulative toxics (PBTs)

In air, a number of pollutants travel regionally or even globally (e.g., ozone, acid deposition, PBTs [including mercury], ozone-depleting substances, greenhouse gases). What do the indicators reveal about baselines and trends in the levels of these pollutants in various ecosystems, or possible harm to biota as a result of exposure to these pollutants or their secondary effects? The chemical and physical characteristic EEA in Exhibit 5-44 contains many Category 2 indicators, but no indicators are available that provide a representative baseline for the nation.

For water, the NAWQA program samples sediment chemistry in more than 500 streams for many PBTs. Repeated sampling should provide an invaluable picture of trends, unless the variability is too high or there are important local sources that make these streams non-representative of streams in general. A smaller number of streams have been sampled for contaminants in fish tissue. A national monitoring network for mercury currently exists, with sampling sites primarily on the East coast and in the upper Midwest (see Chapter 2, Purer Water), but it is not adequate for establishing a national baseline for mercury or other PBTs. Monitoring for UV-B exposure is under development by USDA. EMAP has collected fish tissue residues for many of the PBTs, but there is no commitment to re-sample in the future.

To the extent that these factors affect tree growth, FHM will provide national trends information in the future, but at this point, there is no prospect for establishing trends in either exposure or effects for most of these chemicals.

Future Challenges

When the indicators available for this report are arrayed against the essential attributes in Exhibit 5-44, it is clear that indicators and adequate data are available to address only a portion of the information needed to describe ecological condition for the nation. Data for a few more indicators have been collected once, or for limited geographic regions, but the clear message is that more data are needed to describe and track ecological condition. This situation will improve over the next few years, but most of the gaps in Exhibit 5-44 are likely to remain for some time to come.

There are several challenges to developing adequate indicators of ecological condition for the nation:

- Indicators must be tied to conceptual models that capture how ecosystems respond to single and multiple stressors at various scales.
- Federal, state, and local monitoring organizations must find a way to coordinate and integrate their activities to meet multiple, potentially conflicting, data needs.
- Mechanisms must be found to ensure long-term commitments to measuring selected indicators over long periods and in standardized ways, to establish comparable baselines and trends.
- Indicators must simplify complex data in ways that make them meaningful and useful to decision-makers and the public.

None of these challenges appear insurmountable, but the gaps in Exhibit 5-44 indicate the work that remains to allow measurement of ecological condition at the national scale.